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An Assessment of SeaWiFS and MODIS Ocean Coverage

Robert H. Woodward, General Sciences Corporation, Laurel, Maryland

Watson W. Gregg, Goddard Space Flight Center, Greenbelt, Maryland

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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Abstract

SeaWiFS and MODIS ocean coverages were computed by determining satellite viewing swaths and accounting for interference from sun glint and monthly mean cloud cover. Relative orbital alignments were determined by combining SeaWiFS and MODIS coverages on a global one-degree grid (360 by 180) for ten-degree increments of the MODIS orbital mean anomaly. Bi-modal coverage maxima in the mean anomaly analyses were attributed to gaps between swaths and sun glint contamination. From these analyses the MODIS mean anomalies that produce mean and maximum combined coverages for SeaWiFS and MODIS were computed for one and four-day periods for the spring, summer, fall, and winter seasons.

Ocean coverages were computed on a global one-half degree grid (720 by 360) for the seasonal mean and maximum cases for both one and four-day coverages. Our analyses indicate that MODIS will significantly enhance ocean coverage over one and four-day periods. The combined SeaWiFS/MODIS mean coverage produces an increase in one-day coverage of 40.0% to 46.5% over SeaWiFS alone for the four seasons; the increase in maximum one-day coverage ranges from 44.0% to 51.6%. The increase in four-day coverage for the combined case ranges from 29.3% to 35.1% for mean coverage and 31.6% to 38.5% for maximum coverage.

Meridional distributions of coverages were computed by binning the data into five-degree latitude bands. Our meridional analysis shows a strong seasonal dependence in coverage. In general the greatest increases in coverage for combined SeaWiFS/MODIS over SeaWiFS alone are located near the solar declination.

1.0 Introduction

The importance of oceanic phytoplankton in the carbon cycle has recently gained attention as a major component of the global environment. Over the next decade, a series of orbiting ocean color sensors will be collecting global observations of phytoplankton. These sensors include the Ocean Color and Temperature Sensor (OCTS), the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate Resolution Imaging Spectrometer (MODIS), the Medium Resolution Imaging Spectrometer (MERIS), and the Global Imager (GLI). Gregg *et. al.* (1998) discusses total ocean coverage and the advantages of co-located measurements from these missions. These data will provide the opportunity to characterize global phytoplankton distributions and infer trends.

OCTS was launched in August of 1996 and collected data onboard the Advanced Earth Observing Satellite (ADEOS) satellite from November 1996 to June 1997. The next two missions are SeaWiFS and MODIS. SeaWiFS was launched August 1, 1997 and is currently operating as the sole instrument onboard the SeaStar satellite; MODIS is scheduled to launch in 1999 as one of several instruments onboard the EOS-A platform. In this paper we examine how SeaWiFS and

MODIS complement each other by considering individual and combined ocean coverages over one and four-day periods. These analyses are performed for both the mean and maximum combined coverage cases for four seasons (spring, summer, fall, and winter). Variations in ocean coverages are shown to be primarily a result of seasons, cloud cover, and sun glint. Finally all cases are examined in terms of latitudinal coverage distributions (which we refer to as meridional analysis).

2.0 Coverage Assessment Method

Satellite coverage assessment requires knowledge of satellite position, pointing information, and atmospheric conditions. Gregg *et. al.* (1998) contains a detailed description of all the factors involved in determining ocean coverage from orbiting sensors. We calculated global ocean coverages for SeaWiFS and MODIS by first propagating daily orbits for each satellite from the appropriate orbital elements. A Brouwer-Lyddane general perturbation model with fifth-order gravity was used to generate satellite positions (Kelly, 1991). Some of the attributes for the propagated orbits are listed in Table 1. The proposed orbital characteristics for SeaStar (SeaWiFS) and EOS-A (MODIS) are similar. The equatorial crossing time (ECT) is the primary difference between SeaWiFS, which is in a 1200 (noon) descending orbit, and MODIS, which is in a 1030 AM descending orbit. Eccentricities were set to near zero for both satellites in our analysis, resulting in roughly circular orbits. In subsequent discussions on orbit characteristics we refer to SeaStar as SeaWiFS, and EOS-A as MODIS.

Table 1. Satellite and sensor characteristics for SeaStar/SeaWiFS and EOS-A/MODIS. Ground IFOV refers to instantaneous field-of-view of the sensor.

	SeaStar/SeaWiFS	EOS-A/MODIS
Altitude	705 km	705 km
Inclination	98.2 °	98.2 °
ECT	12:00 Noon	10:30 AM
Node	Descending	Descending
Eccentricity	0.001	0.001
Swath Width	45 °	55 °
Tilt	+- 20 °	None
Ground IFOV	1 km	1 km

Exact geolocation algorithms that compute instrument scans on a geodetic surface were used to compute instrument scan coordinates on the Earth (Patt and Gregg, 1994). This method requires instrument field-of-view, scan width, and instrument tilt for navigating pixel locations. As indicated in Table 1, SeaWiFS tilts 20° fore (-) and aft (+) of the velocity vector to avoid sun glint. At the start of imaging for each orbit the tilt is set to 20° aft. Near the solar declination the tilt changes to 20° fore. In our analysis we used an algorithm that minimizes sun glint contamination to schedule the tilt changes for SeaWiFS. Operationally SeaWiFS employs the staggered tilt algorithm to obtain complete global coverage over a four-day period (Gregg and Patt, 1994).

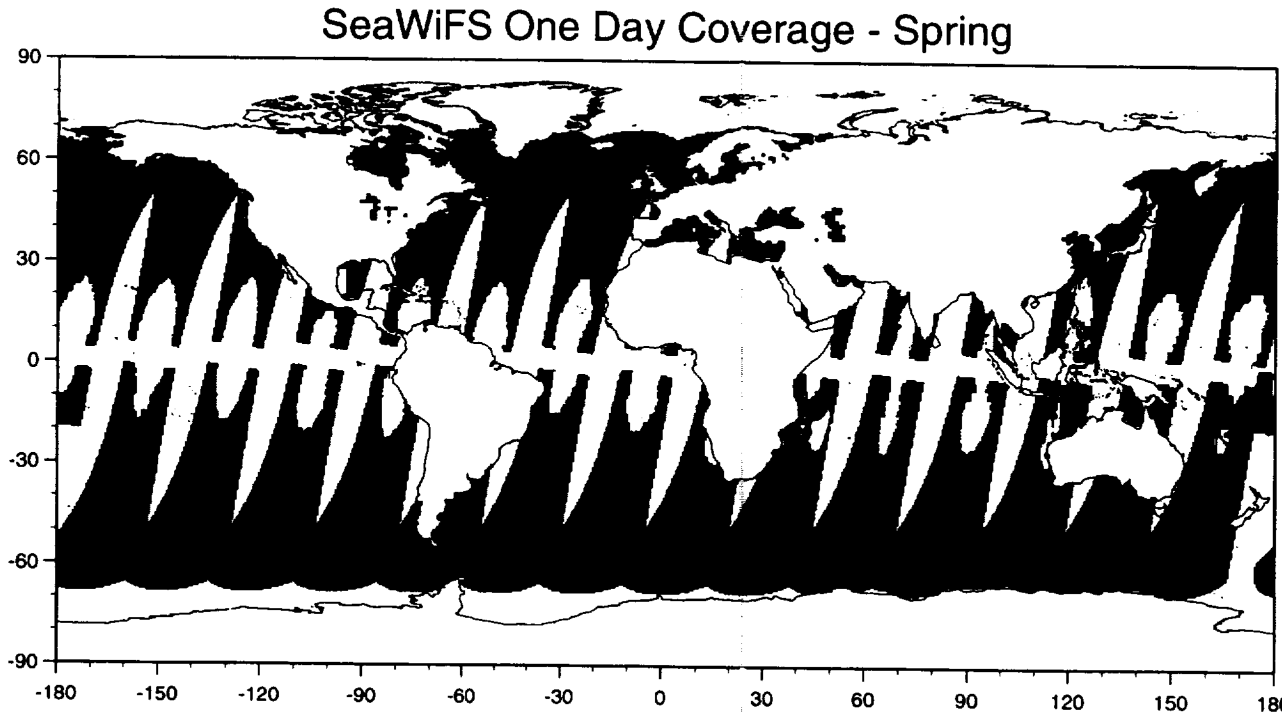
Sun glint can significantly reduce usable ocean data by contaminating water-leaving radiance. Sun glint interference was determined by considering solar and sensor viewing geometry and surface wind speeds. A threshold of 3.5 times the SeaWiFS noise equivalent radiance was used to screen both the SeaWiFS and MODIS sensors for sun glint contamination. Monthly mean surface wind speeds were obtained from six years of data collected by the Fleet Numerical Oceanography Center.

Figure 1 shows typical cloud-free one-day coverages for SeaWiFS and MODIS at the spring equinox. The coverage patterns for both sensors are dominated by the sun glint contamination. The tilting SeaWiFS sensor concentrates the sun glint interference to the center of the swath in the proximity of the solar declination. SeaWiFS also contains an inherent gap in the coverage as a result of the tilt change. This gap is found near the equator for the equinox case that is shown in Figure 1. The non-tilting MODIS sensor contains sun glint contamination over a larger extent of the coverage swath. In addition, the MODIS sun glint is shifted to the east in each orbit as a result of the 1030 ECT orbit. Note also that the loss of coverage due to sun glint contamination for MODIS is somewhat compensated by wider swaths.

Since mean monthly cloud cover is not randomly distributed about the Earth (i.e., more clouds are found in mid-latitudes), it plays a major role in assessing global ocean coverage. We used monthly mean global cloud cover data from the International Satellite Cloud Climatology Project (ISCCP) encompassing the period 1983 - 1988 to create cloud masks. Cloud interference was determined by computing random percentages for each pixel on a daily basis. A pixel was assumed to be viewing clouds and was excluded from analysis if the random percentage exceeded the ISCCP percentage. Daily values were used to simulate synoptic-scale cloud features that change on the order of a day.

3.0 Coverage Analysis

We examined mean and maximum combined coverage scenarios to assess how SeaWiFS and MODIS coverages will complement each other. Coverage data were corrected for sun glint and cloud cover and binned into one-degree (360 by 180) equi-rectangular arrays (-180° to 180° longitude by -90° to 90° latitude). Surface areas of each bin were calculated using a latitudinal weighting function. A land mask was used to screen pixels falling on land. All coverages were therefore computed for total ocean area.



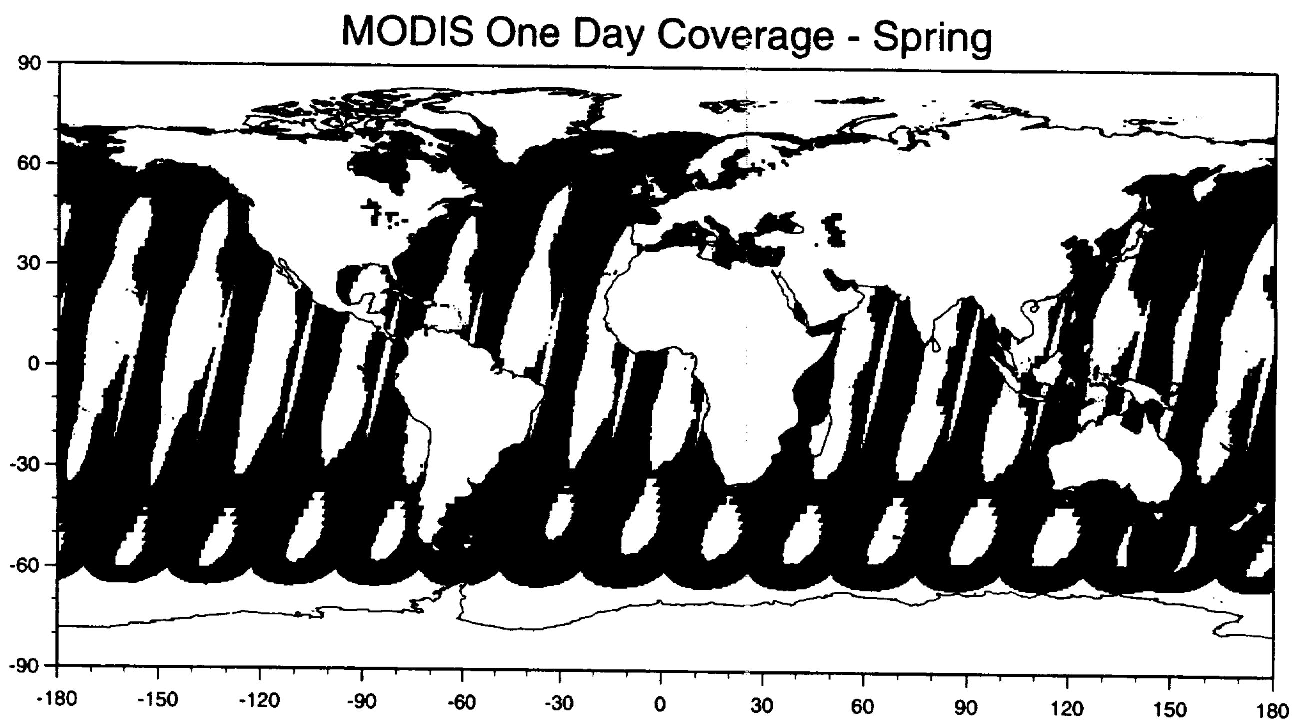


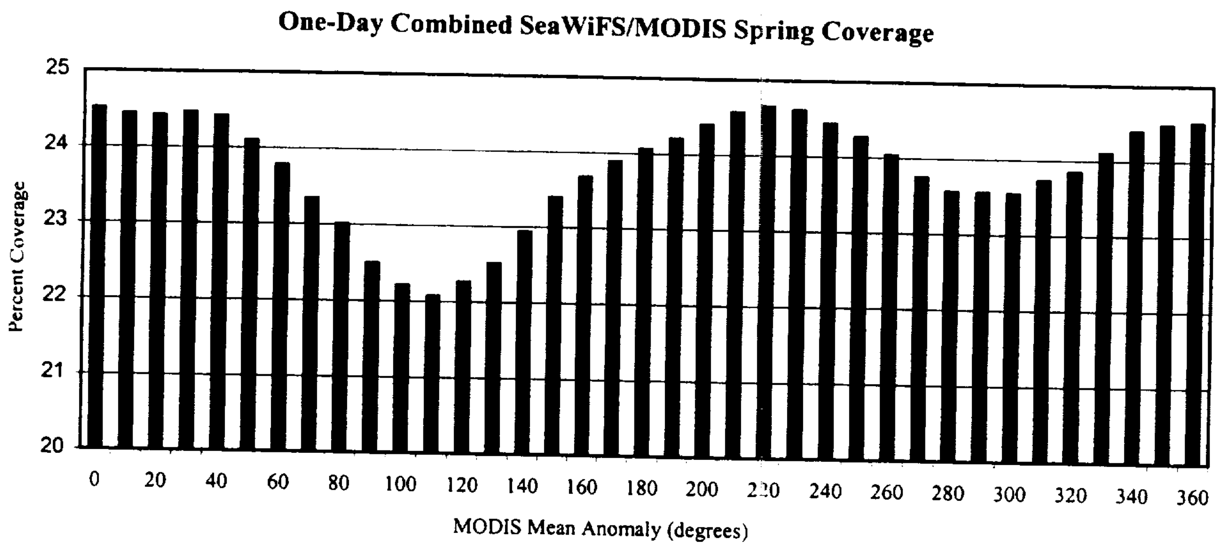
Figure 1. One-day, cloud-free ocean coverages for SeaWiFS and MODIS at the Spring equinox. Note that SeaWiFS is a tilting instrument and MODIS is a non-tilting instrument. SeaWiFS tilt changes can be identified by the coverage gap near the equator where the instrument changes tilt from +20 degrees to -20 degrees.

3.1 Mean Anomaly Analysis

The relative importance of satellite positions on combined coverage was determined using a method similar to the one described in Gregg *et. al.* (1998). We varied the mean anomaly of MODIS by 10° increments over 0° to 360° while holding SeaWiFS mean anomaly constant at 0°. This procedure altered the relative positions of the two satellites to examine possible coverage scenarios. Next the MODIS and SeaWiFS coverages were combined and total coverages were computed as a percentage of the global ocean surface. These analyses were performed for both one-day and four-day coverages for spring equinox, summer solstice, fall equinox, and winter solstice. The equinox cases are somewhat symmetrical about the equator in coverage. The solstice cases represent extremes in the global coverage pattern as the coverages migrate north and south with the solar declination.

Figures 2 (a and b) and 3 (a and b) show the results of the seasonal mean anomaly analyses for one and four-day coverages respectively. The relationship between combined coverage and MODIS mean anomaly can be understood by considering the relative location of the coverage swaths and sun glint contamination patterns. SeaWiFS is a tilting instrument in a 1200 ECT descending orbit with a 45° swath; MODIS is a non-tilting instrument in a 1030 ECT descending orbit with a 55° swath. Coverage analysis is somewhat complicated by the variable sun glint patterns produced by differences in the instrument configurations and satellite orbits. These effects contribute to the combined coverage exhibiting a bi-modal relationship to variations in the MODIS mean anomaly. SeaWiFS loses coverage as a result of two effects: sun glint and non-overlapping swaths. MODIS loses coverage only as a result of sun glint (Figure 1). Note that MODIS coverage contains only small gaps between swaths. The relative maxima in the bi-modal relationship are a result of the MODIS sun glint pattern first overlapping the SeaWiFS inter-swath regions and then overlapping the SeaWiFS sun glint contamination.

It is interesting to note the different coverages obtained by altering the MODIS mean anomaly as shown in Figures 2 and 3. The combined coverages range between 21% and 26% for the one-day analysis and between 54% and 64% for the four-day analysis. The bi-modal relative minima for both the one and four-day spring case display an asymmetry. This is a result of the SeaWiFS inter-swath region contributing more than the SeaWiFS sun glint contamination to the combined coverage loss. The relative minimum for the inter-swath region occurs at a MODIS mean anomaly of 110° (22.1% coverage for one-day and 58.1 % for four-day), the relative minimum for the sun glint contamination occurs at a MODIS mean anomaly of 300° (23.6% for one-day and 60.2% for four-day). The one and four-day mean anomaly analysis for the fall equinox case display a pattern similar to the spring case. The one-day analysis for the summer and winter cases are more symmetrical due the diminished importance of the SeaWiFS inter-swath regions for these cases. The asymmetry in the relative maxima for the four-day winter case (Figure 3b) is a result of MODIS swaths contributing more to the total coverage when the swaths are aligned with the SeaWiFS inter-swath regions then when the swaths are aligned with the SeaWiFS sun glint.



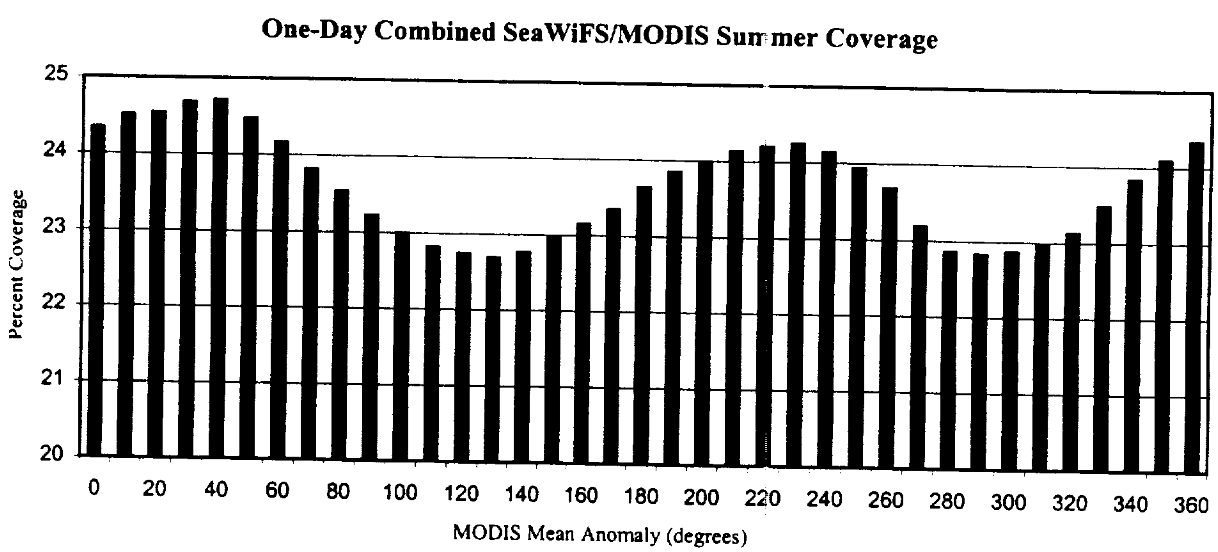
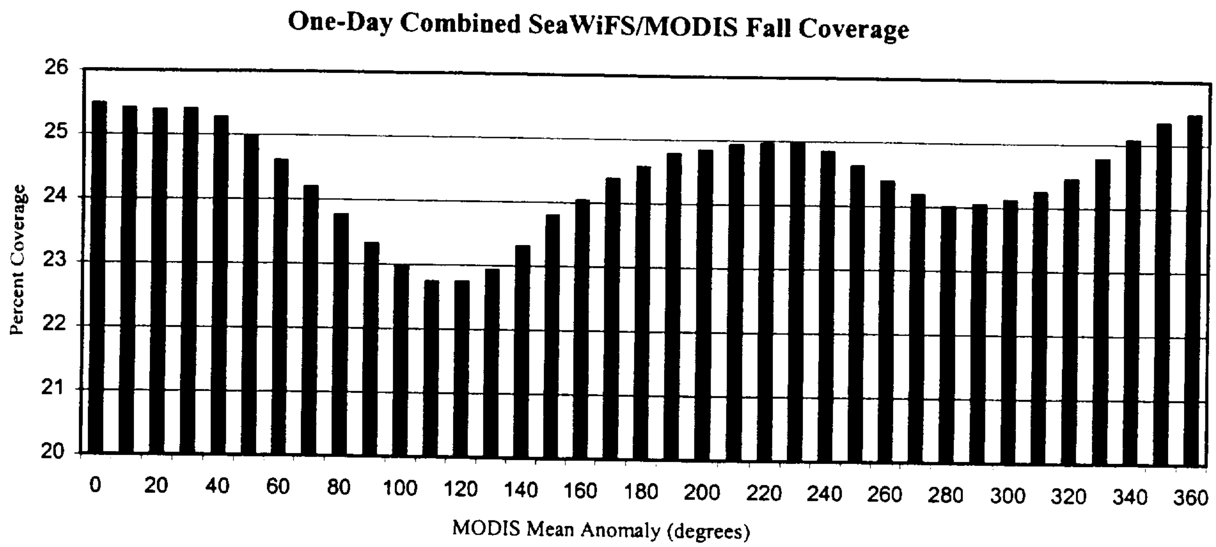


Figure 2a. One-day combined SeaWiFS/MODIS coverage as a function of MODIS mean anomaly for spring and summer.



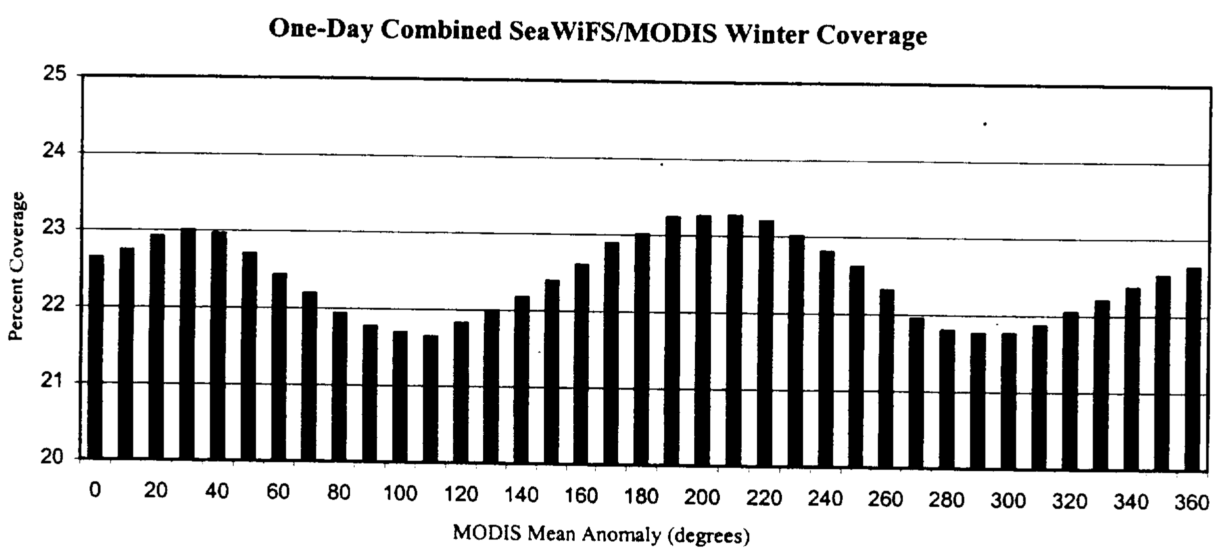
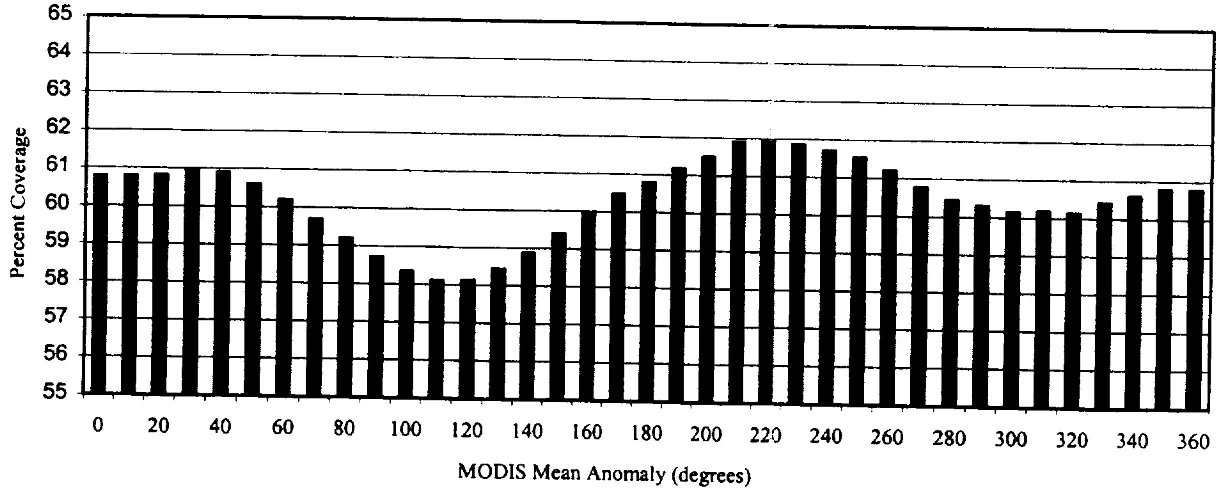


Figure 2b. One-day combined SeaWiFS/MODIS coverage as a function of MODIS mean anomaly for fall and winter.

Four-Day Combined SeaWiFS/MODIS Spring Coverage



Four-Day Combined SeaWiFS/MODIS Summer Coverage

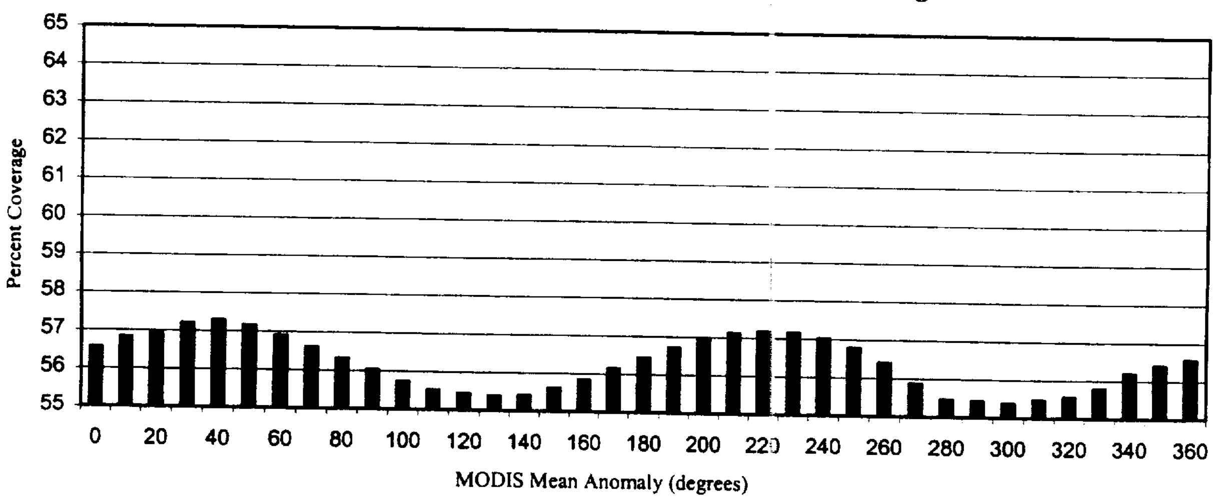
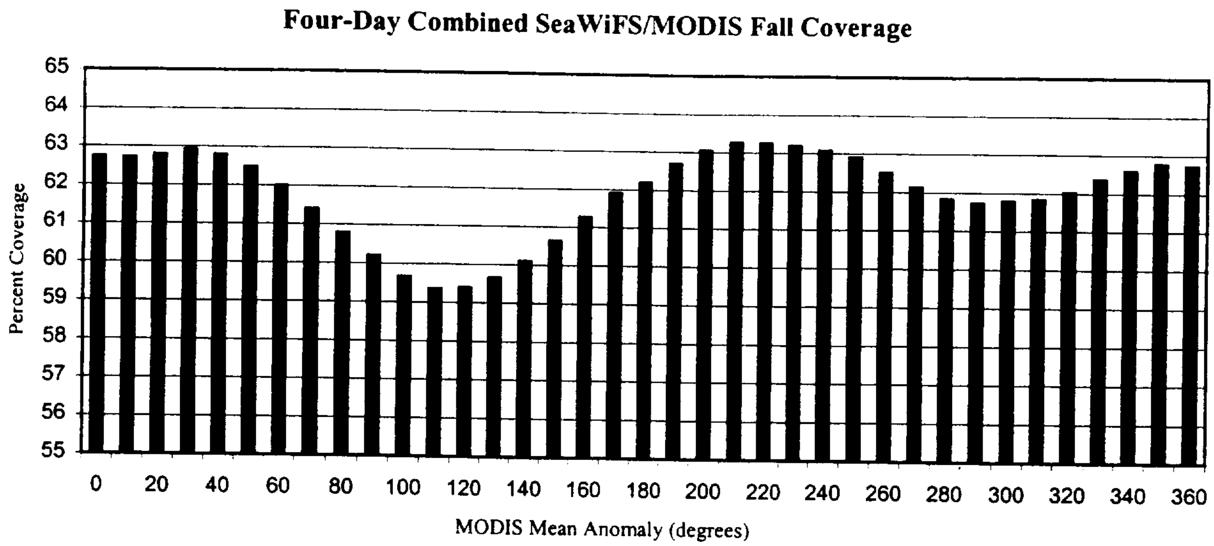


Figure 3a. Four-day combined SeaWiFS/MODIS coverage as a function of MODIS mean anomaly for spring and summer.



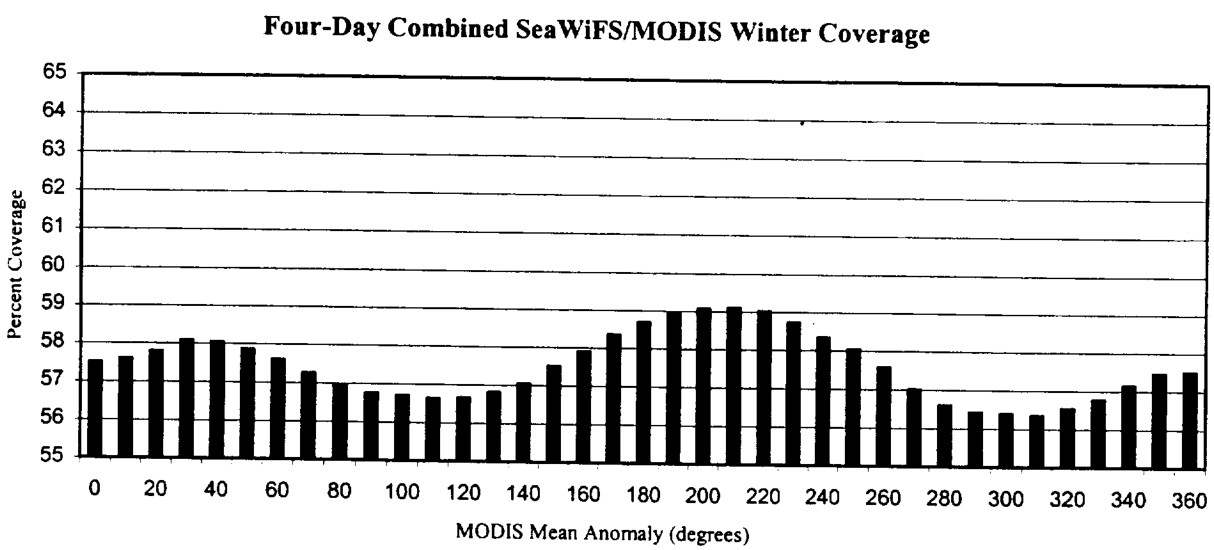


Figure 3b. Four-day combined SeaWiFS/MODIS coverage as a function of MODIS mean anomaly for fall and winter.

The above analysis suggests that relative difference in mean anomalies is important in assessing combined coverages. We calculated the MODIS mean anomaly that produced both the mean and maximum coverage combinations for all four seasons for both one and four-day coverages (Table 2). These values were then used to create SeaWiFS and MODIS coverages for the 0.5-degree analysis described below.

Table 2. The MODIS mean anomaly that provides mean and maximum one-day coverage for combined SeaWiFS and MODIS.

	Spring	Summer	Fall	Winter
One-Day Mean	60.0°	76.9°	64.6°	60.0°
One-Day Maximum	220.0°	40.0°	0.0°	210.0°
Four-Day Mean	56.5°	81.1°	61.9°	3.3°
Four-Day Maximum	220.0°	40.0°	210.0°	210.0°

3.2 Global Coverage

We used 0.5-degree grids to compute coverages for both mean and maximum global coverage analyses: daily coverages were computed for equi-angular bins at a resolution of 720 (-180° to 180° longitude) by 360 (-90° to 90° latitude). SeaWiFS orbits were propagated for four days starting at the spring equinox using a mean anomaly of zero. MODIS coverages were then propagated for the same period using the mean anomaly associated with the mean and maximum coverage cases for both the one and four-day analysis. The combined coverages were then computed for all the cases on the 0.5-degree grid. The above coverage analysis was then repeated for the summer solstice, fall equinox, and winter solstice cases.

Figure 4 displays one-day, cloud-free mean coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS for all four seasonal cases. Figure 5 displays the same for the maximum coverage cases. We display the cloud-free coverages in these figures to clarify features. Our subsequent analyses on coverages include the effects of clouds. The analyses we show in Figures 4 and 5 point out several factors in considering coverages. The seasonal dependency is clearly shown as the coverages move north in the summer and south in the winter. These figures suggest that MODIS contributes most to the combined coverage over areas near the solar declination for each season. For spring and fall the declination is near 0° latitude (equator), for summer the declination is near 23.5° north, and for winter the declination is near 23.5° south. The enhanced combined coverage near the declination is a result of two factors: the non-tilting nature of the MODIS instrument and the larger scan width for MODIS. The tilting SeaWiFS instrument significantly reduces sun glint contamination away from the declinations particularly at mid-latitudes. However the tilt change produces an inherent gap in the coverage near the declination where the tilt occurs. This data gap is somewhat filled by MODIS coverage due to nadir pointing and wider coverage swaths. This is especially true for the maximum coverage case (Figure 5). However even for the maximum coverage case, the worst combined coverage still occurs near the declination. Figure 6 displays the same analysis shown in Figure 5 except the effect of seasonal cloud cover has been added. Note the relative increase in cloud cover near the mid-latitudes (30° to 60°) in both hemispheres.

Table 3 lists the one-day coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS and the percent increase for combined over SeaWiFS alone for the one-day analysis with the effects of clouds taken into account. This analysis points out the enhancement in coverage obtained by supplementing SeaWiFS with MODIS. Increases range from 40.0% to 46.5% for the one-day mean coverage case; increases range from 44.0% to 51.6% for the one-day maximum coverage case.

The results in Tables 3 also point out the asymmetry in global ocean coverages between the summer and winter solstice cases. The overall coverage moves north for the summer case and south for the winter case. The asymmetry is due in part to the global distribution of land: the Northern Hemisphere contains more land and this, in turn, affects the sun glint pattern. The proximity of land to the solar declination decreases sun glint contamination.

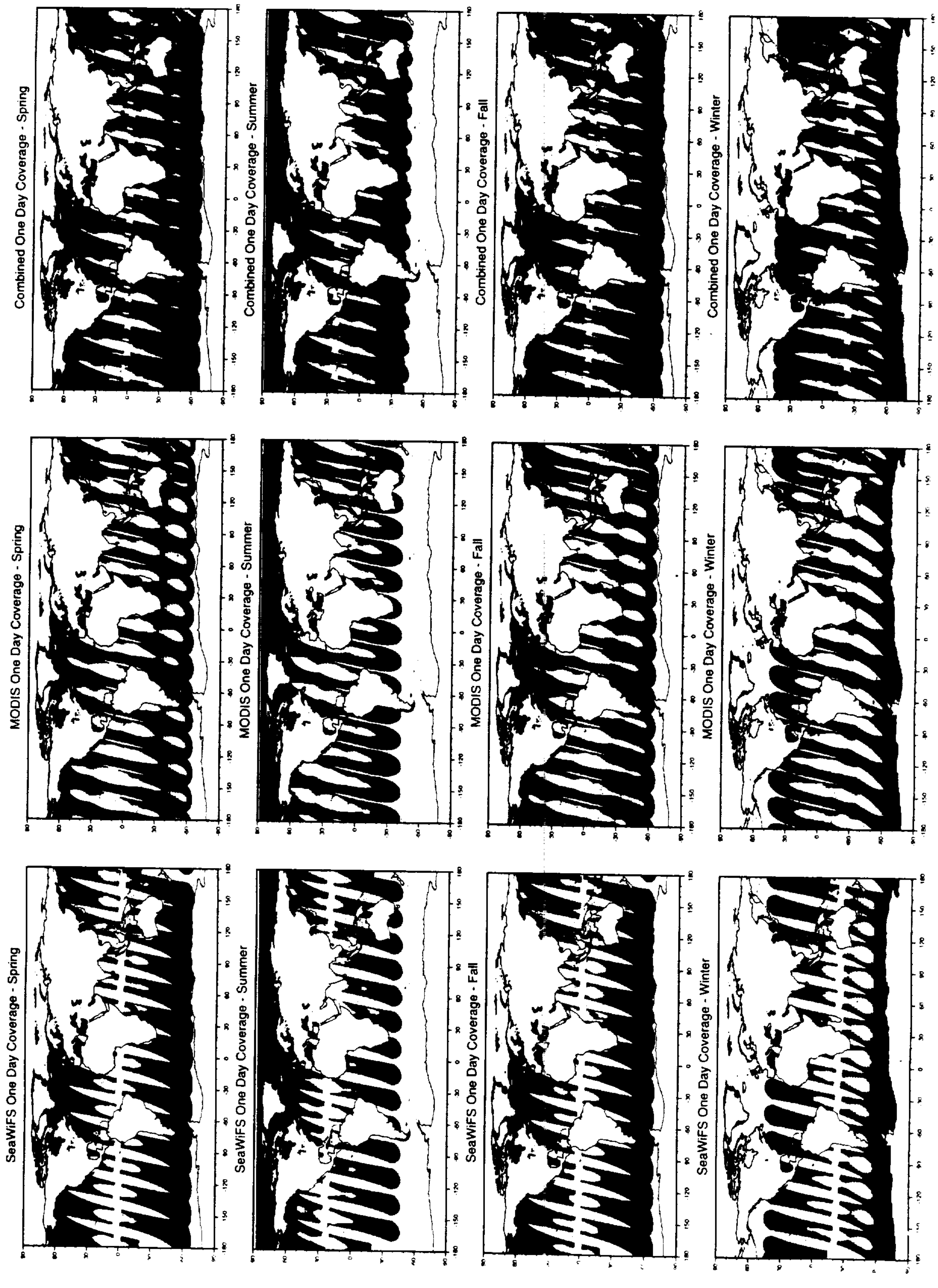


Figure 4. One-day, cloud-free ocean coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS for the mean coverage cases. Note how MODIS adds to the combined coverages in areas near the solar declination (this area can be identified by the tilt change gap on the SeaWiFS plots).

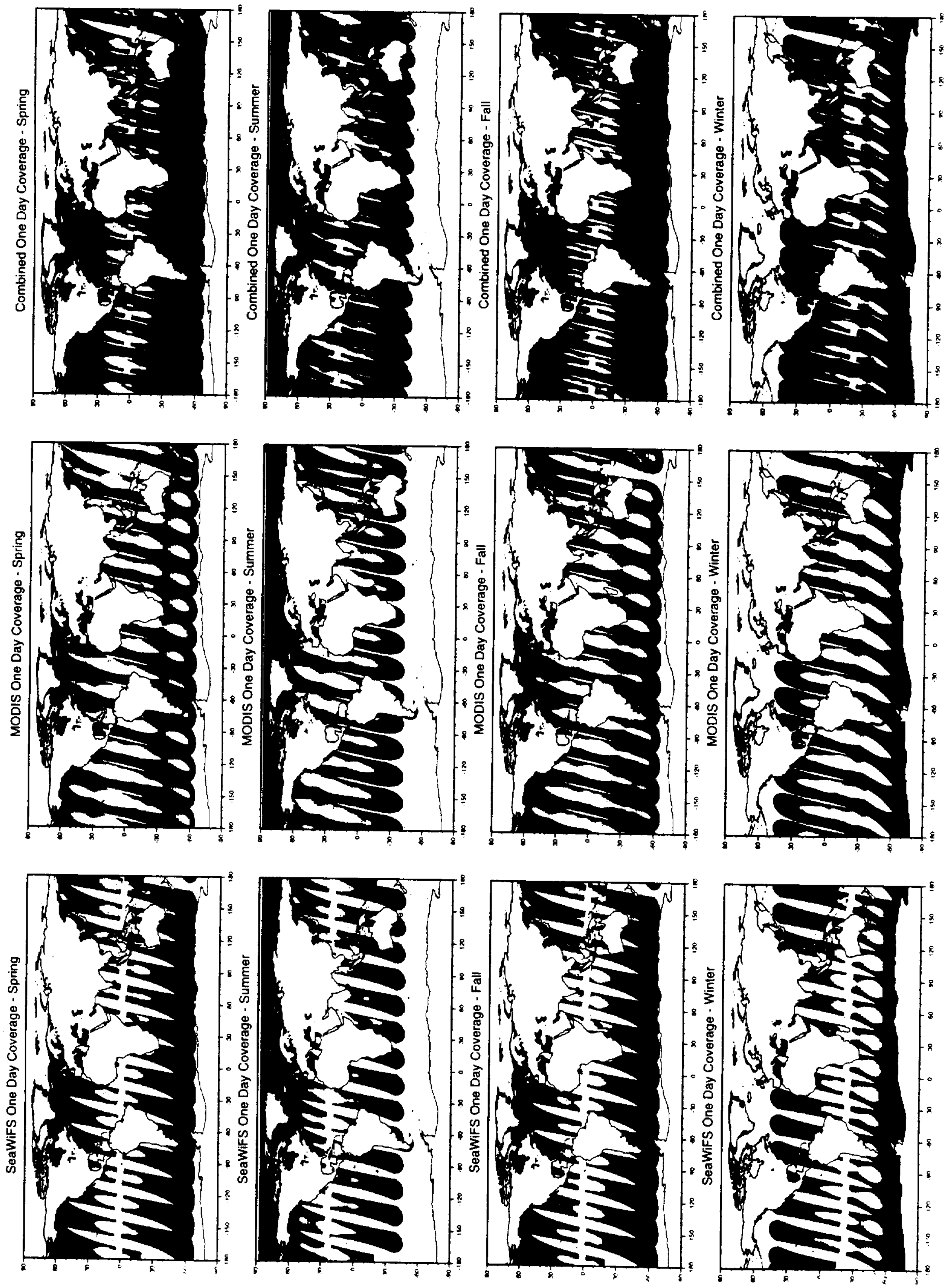


Figure 5. One-day, cloud-free ocean coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS for the maximum coverage cases. Note the improved combined coverage over that shown in Figure 4.

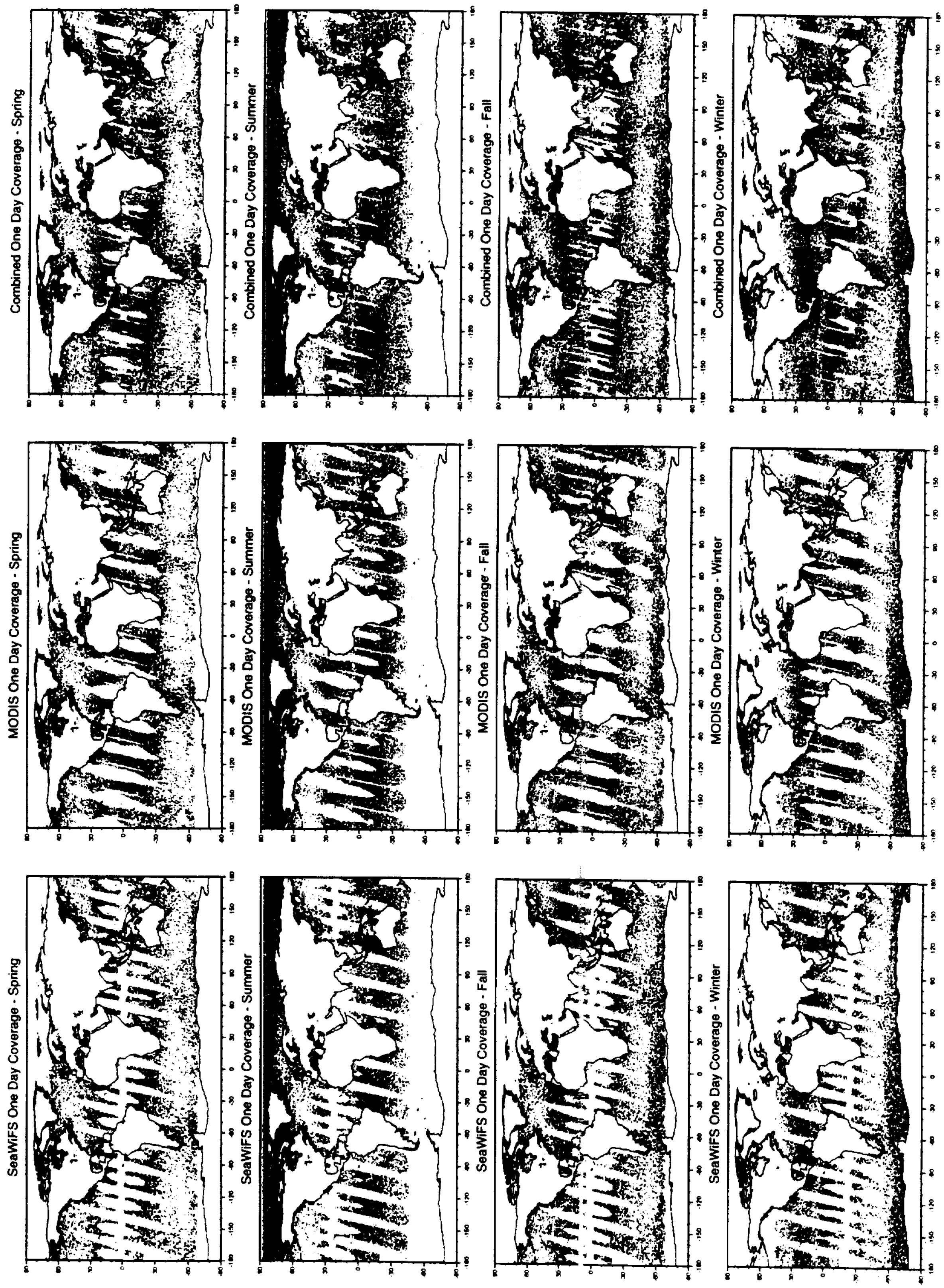


Figure 6. One-day ocean coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS for the maximum coverage cases. The effects of cloud cover are included.

Table 3. One-day global ocean coverage (%) for SeaWiFS, MODIS, and combined SeaWiFS/ MODIS. The effects of mean monthly climatological cloud cover and wind speeds are included.

Season	SeaWiFS	MODIS	SeaWiFS+MODIS	Percent Increase
Mean Coverage Spring	15.7	18.4	23.0	46.5
Mean Coverage Summer	16.5	19.0	23.1	40.0
Mean Coverage Fall	16.8	19.3	23.8	42.7
Mean Coverage Winter	15.2	17.8	22.0	44.7
Maximum Coverage Spring	15.7	17.4	23.8	51.6
Maximum Coverage Summer	16.5	19.0	24.1	46.1
Maximum Coverage Fall	16.8	18.3	24.2	44.0
Maximum Coverage Winter	15.2	16.8	22.8	50.0

The above analysis was repeated for four-day coverages. Figures 7 and 8 show the mean and maximum four-day coverages with the effects of monthly cloud cover included. The analysis with cloud cover is shown here to highlight the seasonal distribution of clouds. The four-day coverages are listed in Table. 4. Once again MODIS contributes significantly to the total coverage, although the increase in coverages in not as great as the one-day case. Increase in coverages range from 29.3% to 35.1% for the mean coverage case and 31.6% to 38.5% for the maximum coverage case.

Table 4. Four-day global ocean coverage (%) for SeaWiFS, MODIS, and combined SeaWiFS/MODIS. The effects of climatological cloud cover are included.

Season	SeaWiFS	MODIS	SeaWiFS+MODIS	Percent Increase
Mean Coverage Spring	43.6	50.8	58.9	35.1
Mean Coverage Summer	42.7	47.7	55.2	29.3
Mean Coverage Fall	46.0	52.8	60.6	31.7
Mean Coverage Winter	41.7	48.7	55.7	33.6
Maximum Coverage Spring	43.6	51.0	60.4	38.5
Maximum Coverage Summer	42.7	47.9	56.2	31.6
Maximum Coverage Fall	46.0	53.1	61.8	34.3
Maximum Coverage Winter	41.7	48.7	57.6	38.1

The global coverage analysis described above (Figures 4 through 8) indicates a strong seasonal dependence of coverage with latitude (meridional direction). We performed additional coverage analysis to deduce meridional patterns in single and combined coverages for each season for both mean and maximum coverage cases. The coverages were binned into five-degree latitudinal bands and coverage percentages were computed for each latitudinal band. Figures 9a (spring and summer) and 9b (fall and winter) show the meridional analysis for the mean coverage one-day case for spring, summer, fall, and winter. Figures 10a and 10b show the same for the maximum coverage one-day case. Figures 11a and 11b show the meridional analysis for the mean coverage four-day case. Figures 12a and 12b show the same for the maximum coverage four-day case. In general these analyses suggest that the strongest contribution of MODIS to the total coverage is located near the solar declination.

Meridional coverages for the mean coverage cases (Figures 9 and 11) are tabulated in Tables 5 to 12. The percent gained by combining SeaWiFS with MODIS over SeaWiFS alone are also listed. This analysis verifies the enhancement in coverage for the combined cases for each season near solar declination. We calculated a greater than 1200% increase in ocean coverage for the combined case over the SeaWiFS only case at the equator for spring equinox for the mean coverage case (Table 5). This large increase is a result of the paucity of SeaWiFS coverage caused by the tilt change in this region. The mean four-day spring analysis shows a lesser enhancement of coverage at the equator (Table 9). The summer and winter cases also show a marked enhancement in coverage at the solar declination, but not as pronounced as the spring and fall cases.

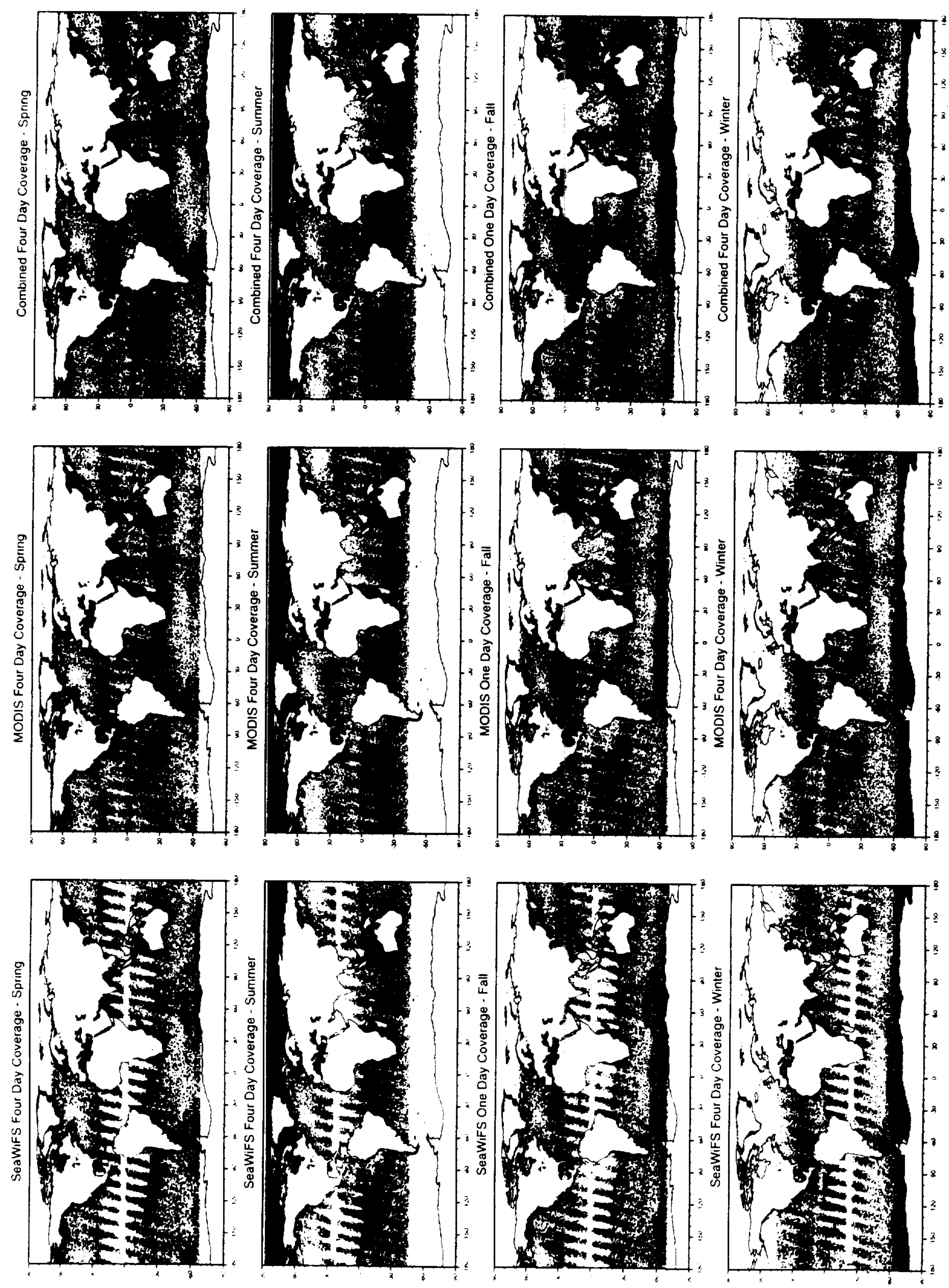


Figure 7. Four-day ocean coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS for the mean coverage cases. The effects of cloud cover are included. Note that cloud cover is more prominent over the mid-latitudes (-30° to -60°., 30° to 60°).

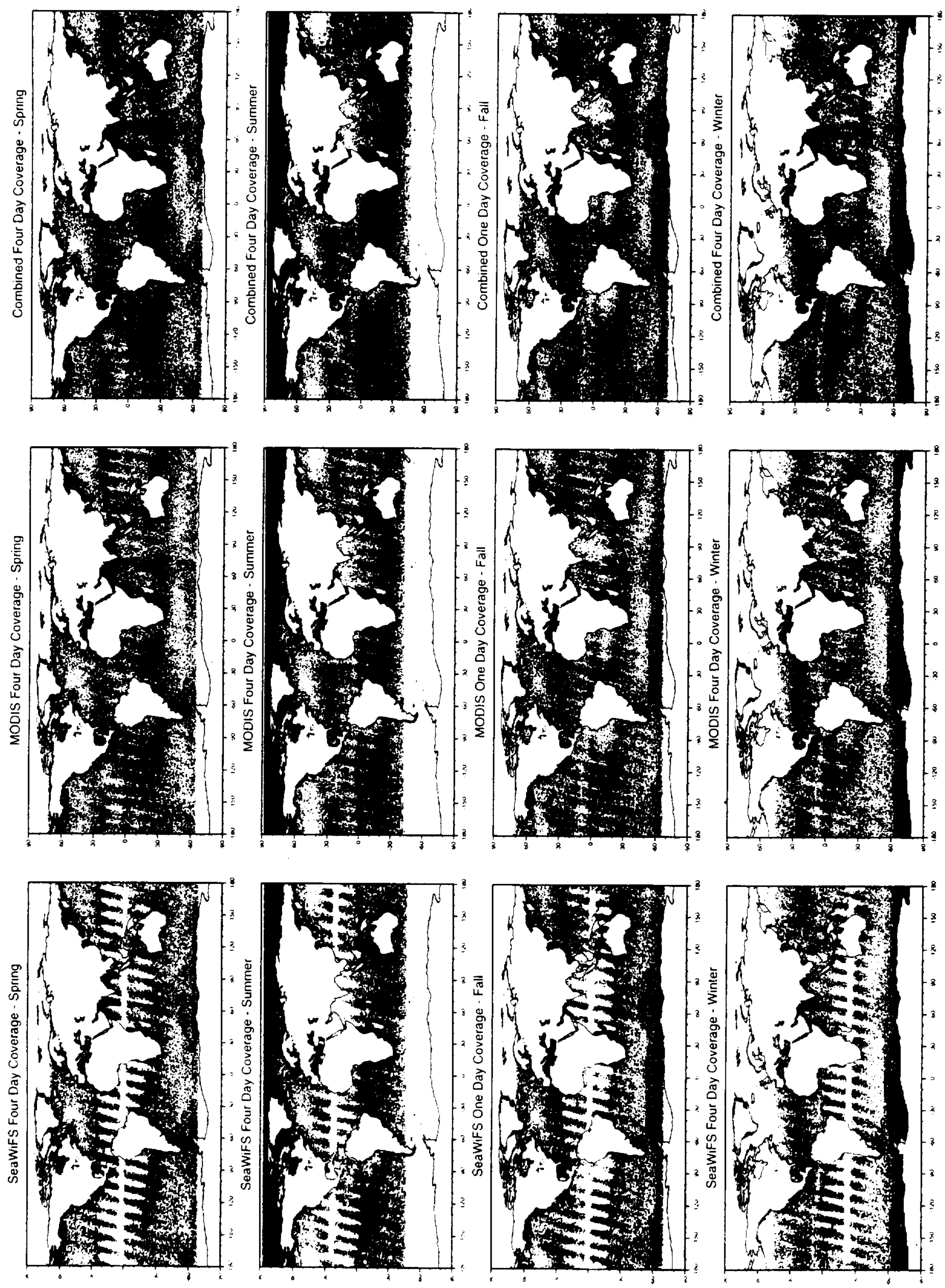
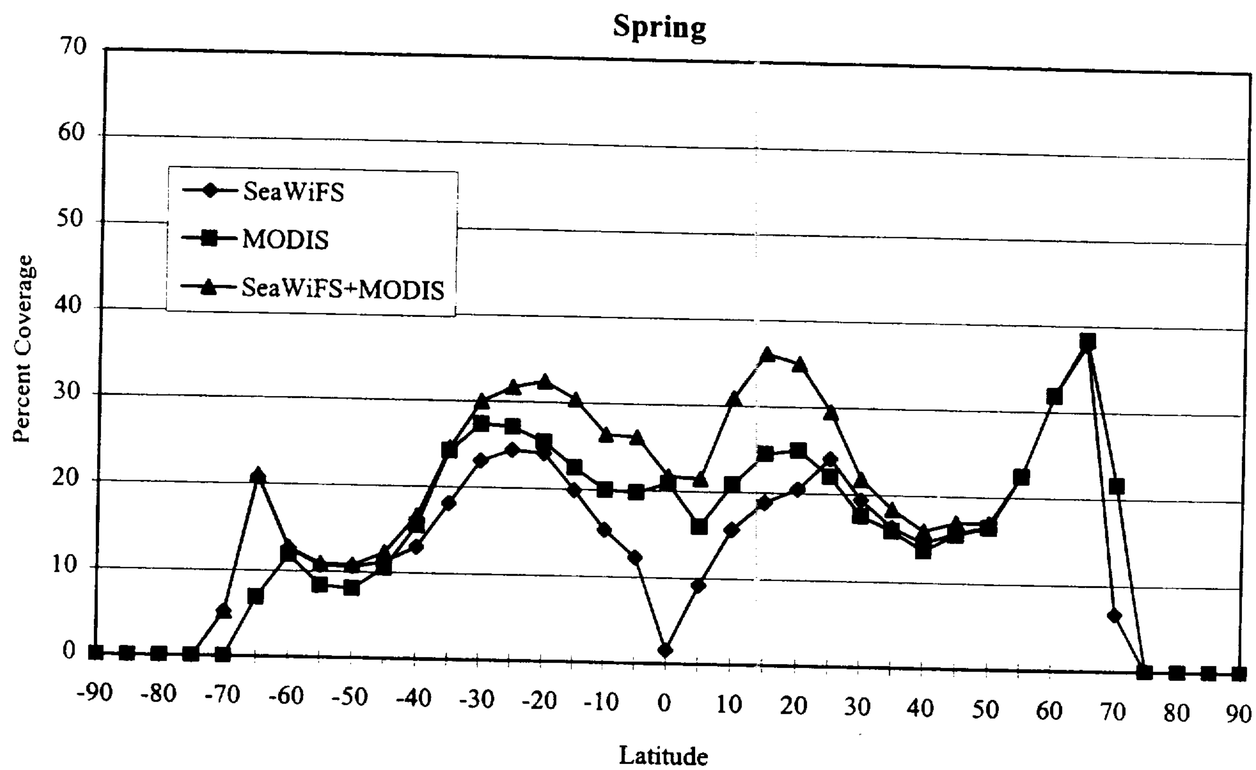


Figure 8. Four-day ocean coverages for SeaWiFS, MODIS, and combined SeaWiFS/MODIS for the maximum coverage cases. The effects of cloud cover are included.



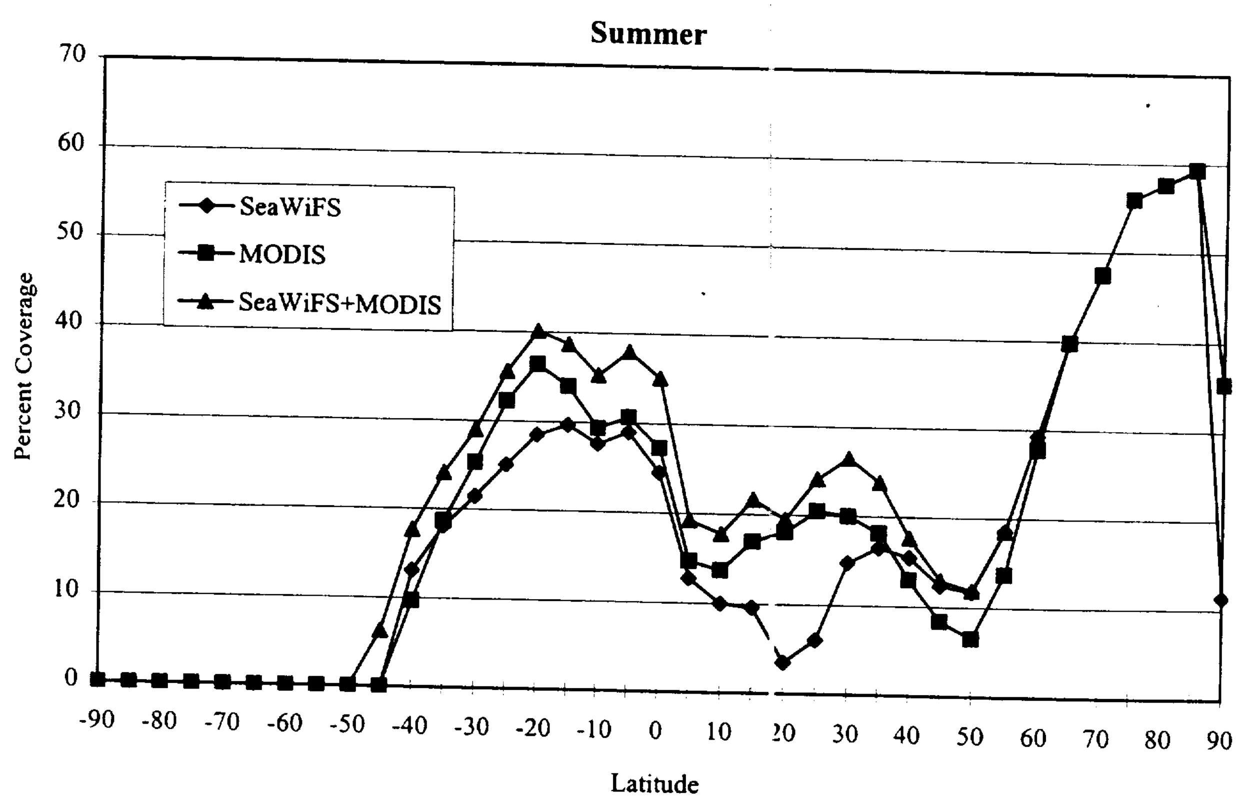


Figure 9a. Meridional analysis of mean one-day coverage for spring and summer.

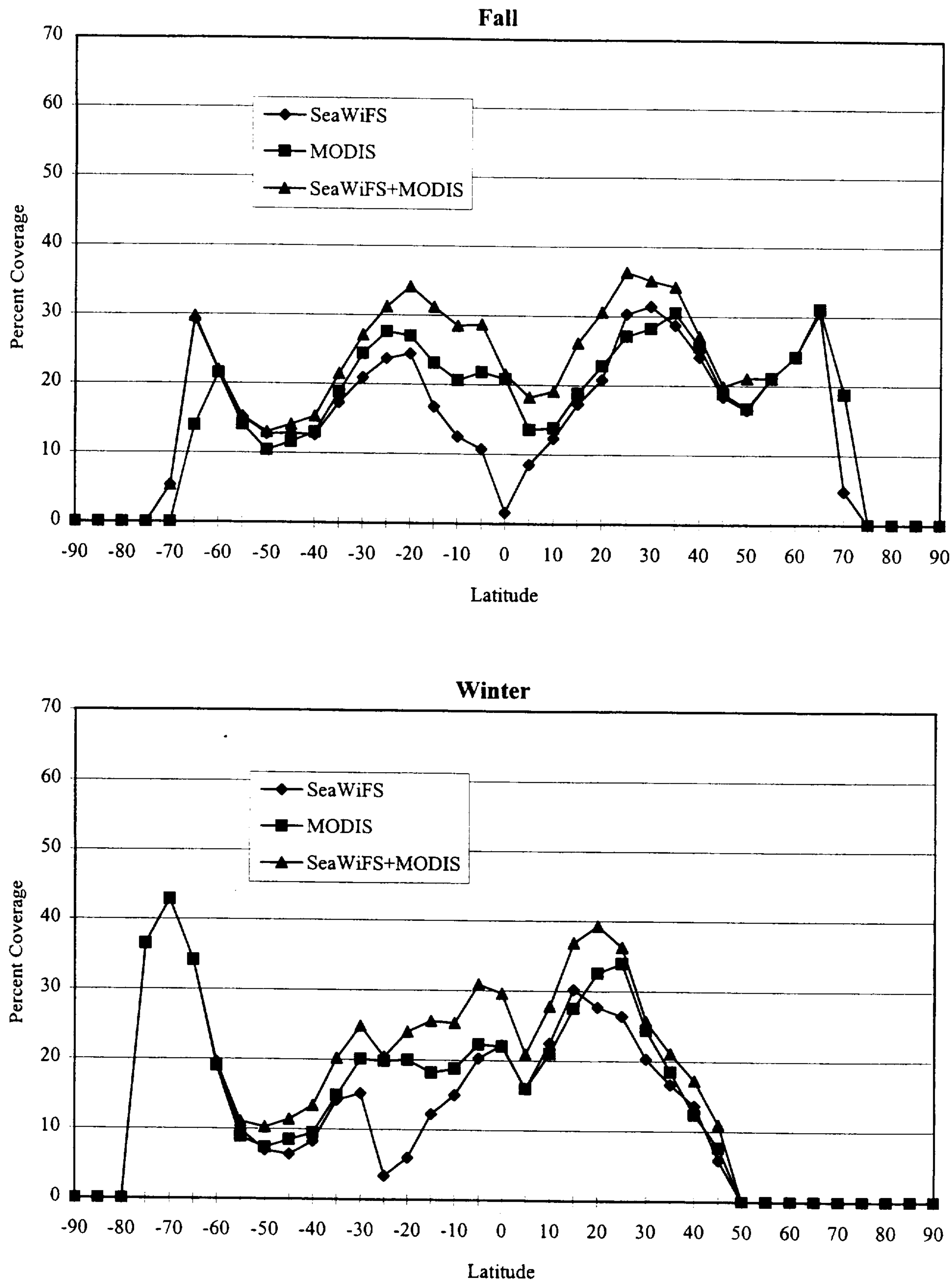
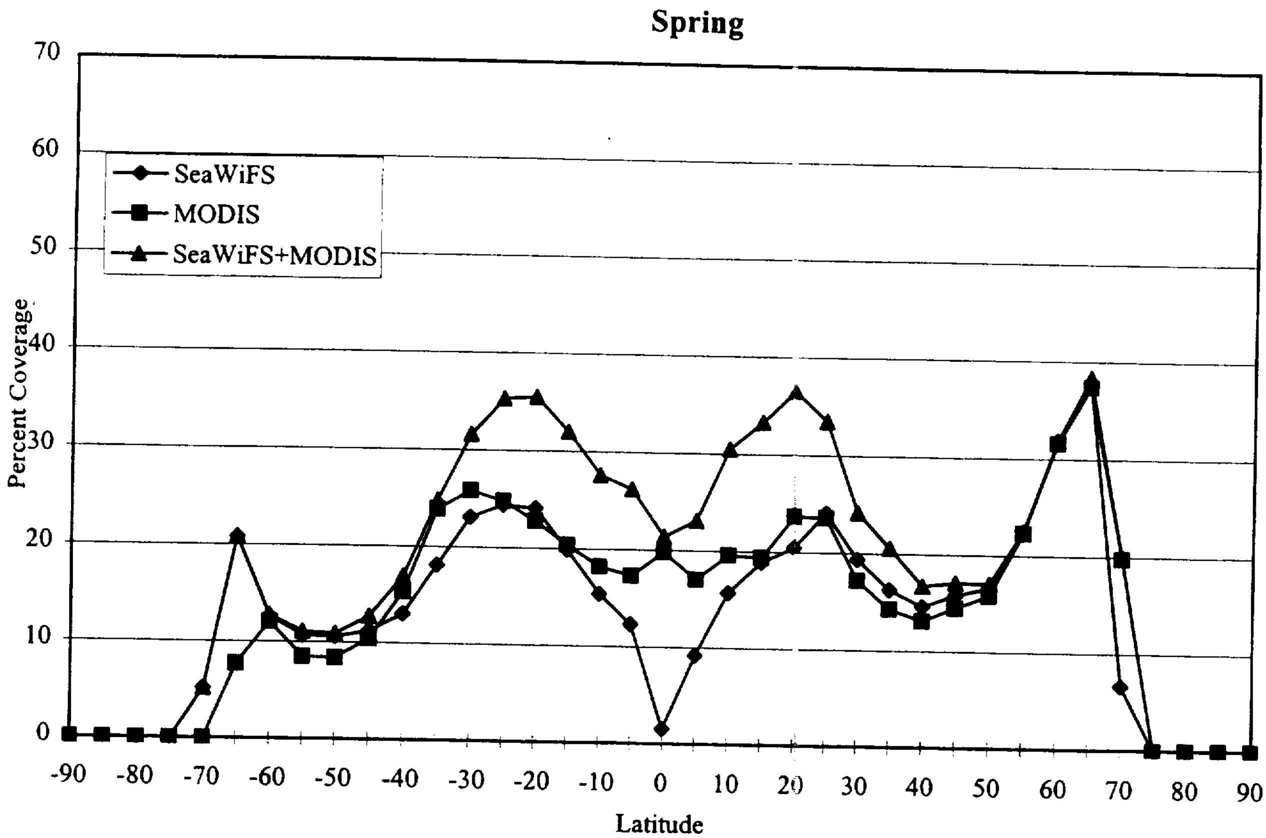


Figure 9b. Meridional analysis of mean one-day coverage for fall and winter.



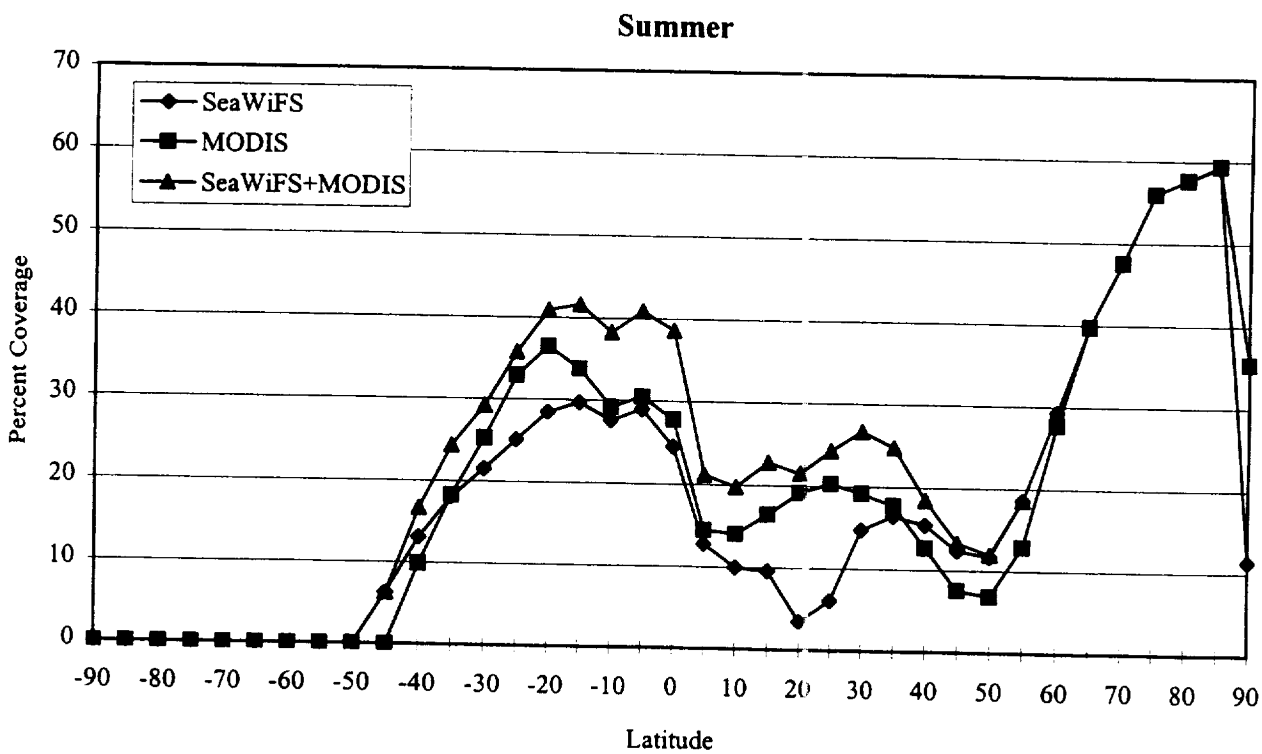
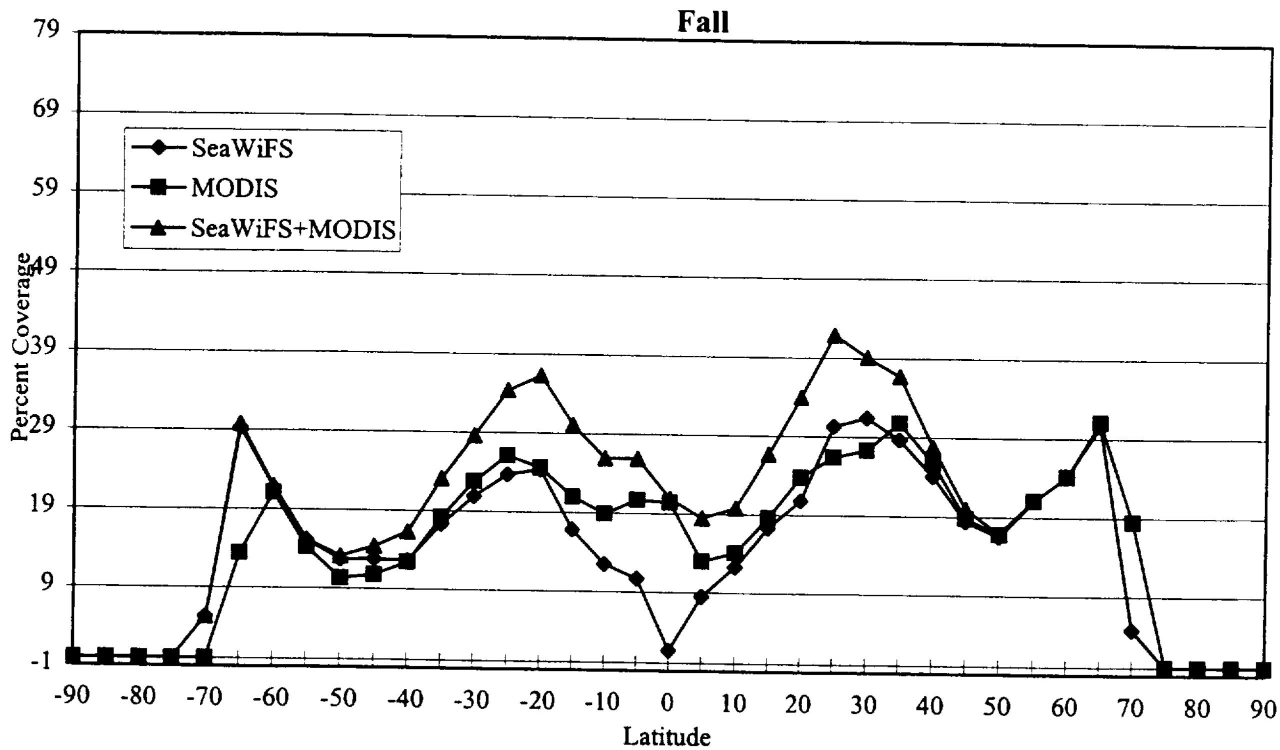


Figure 10a. Meridional analysis of maximum one-day coverage for spring and summer.



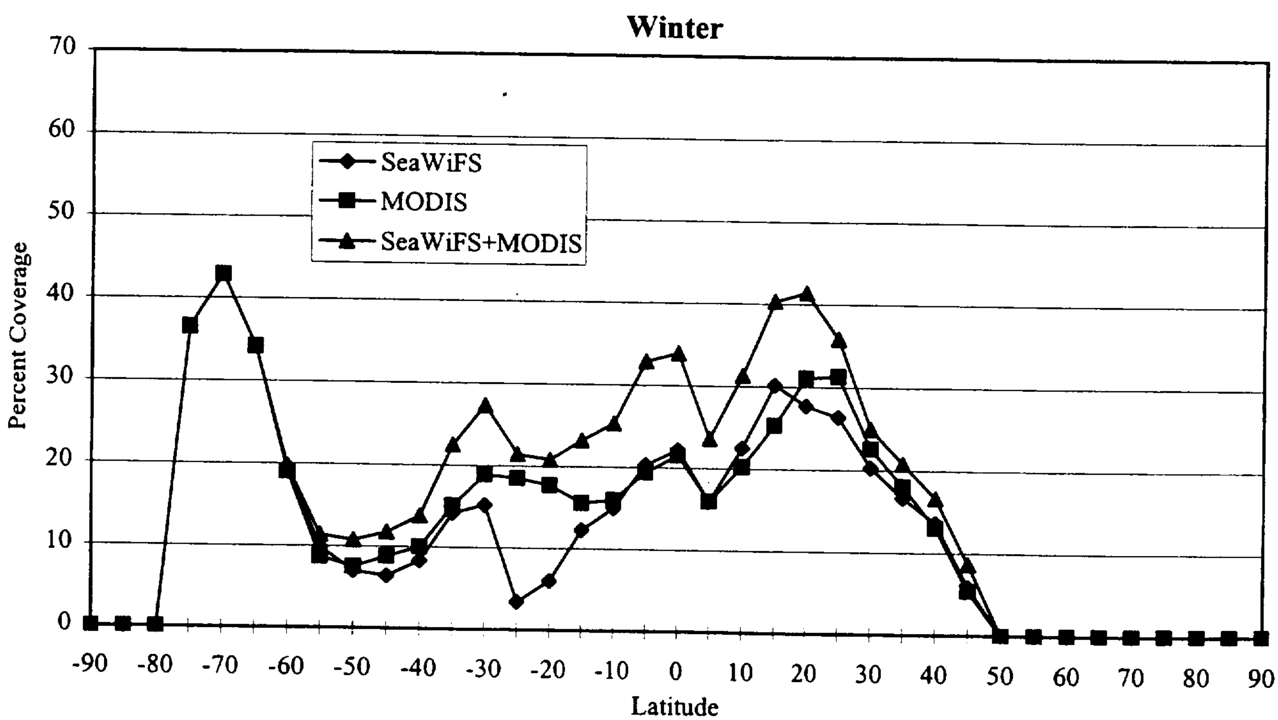
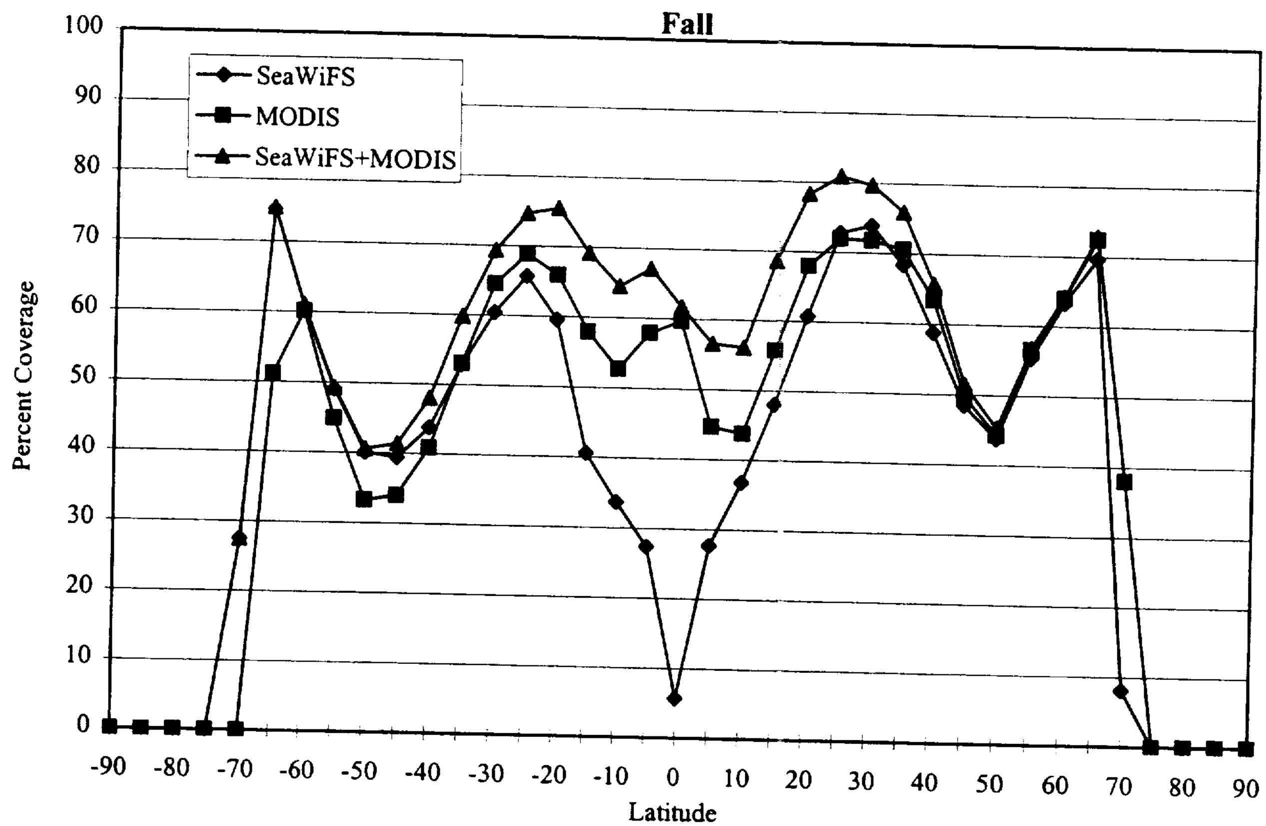


Figure 10b. Meridional analyis of maximum one-day coverage for fall and winter.



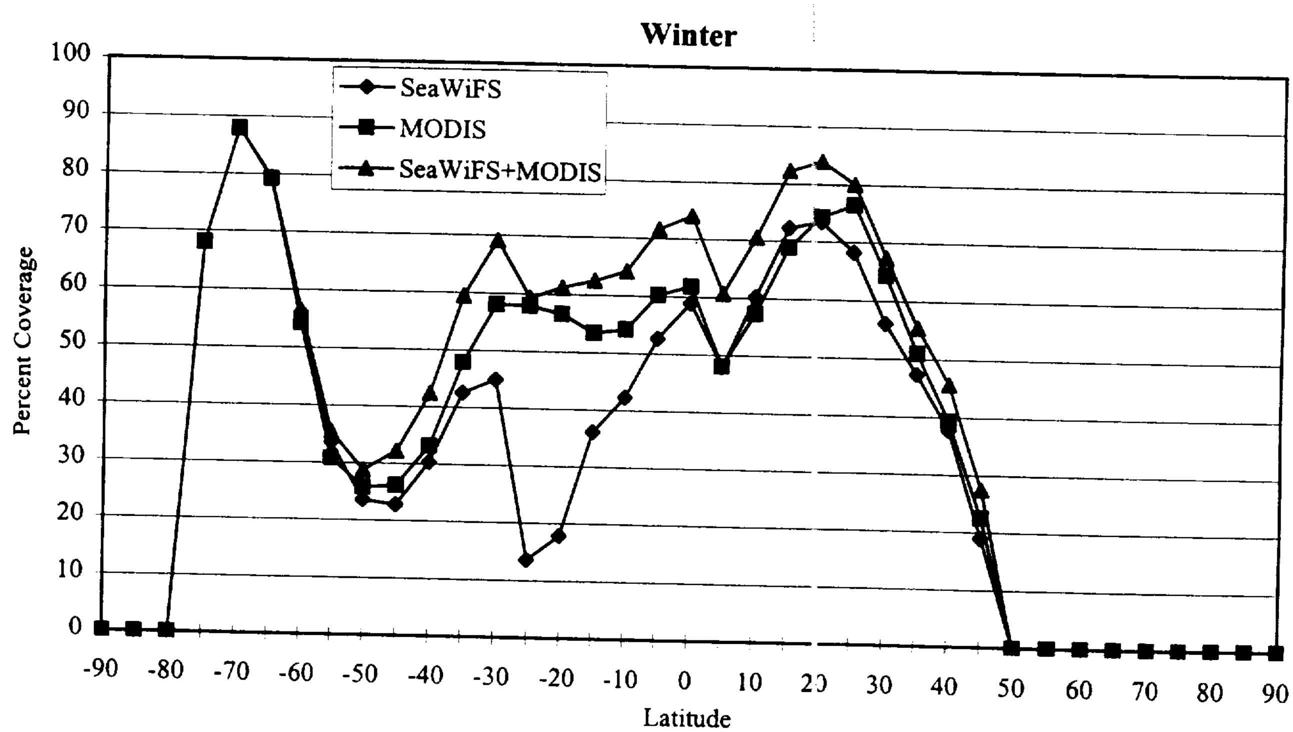
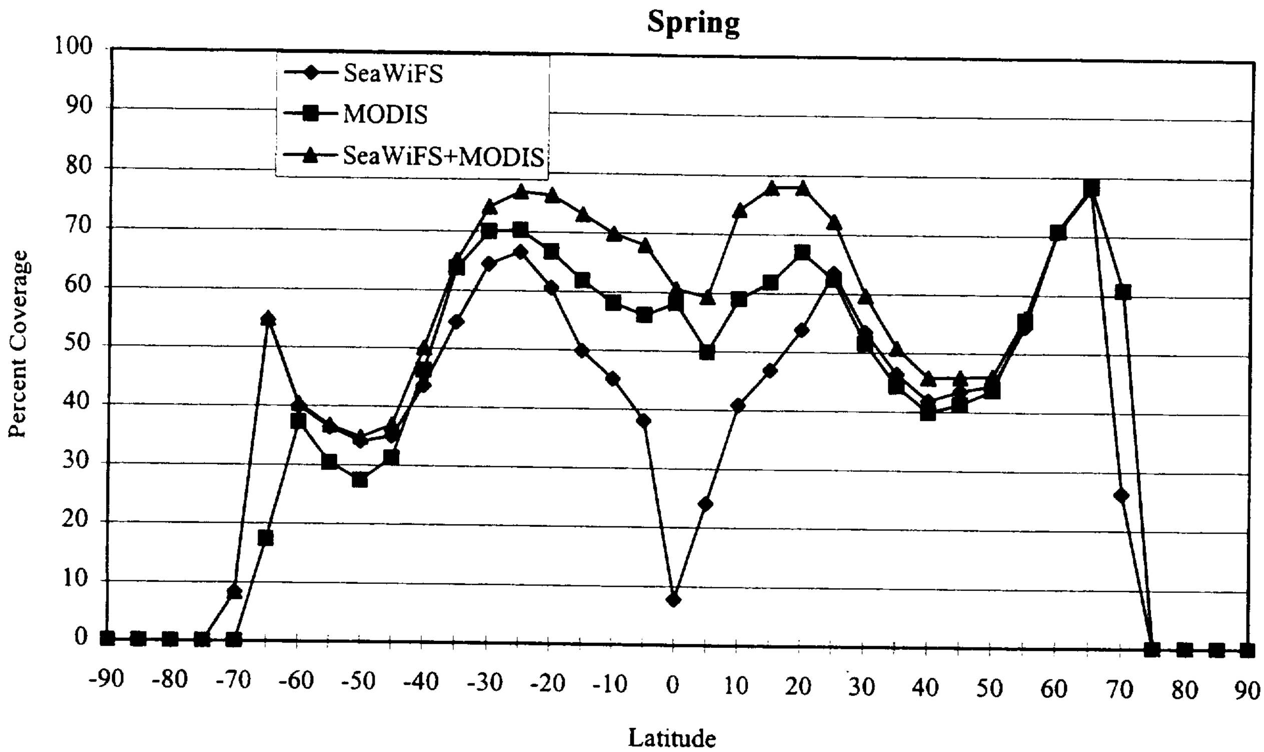


Figure 11b. Meridional analyis of mean four-day coverage for fall and winter.



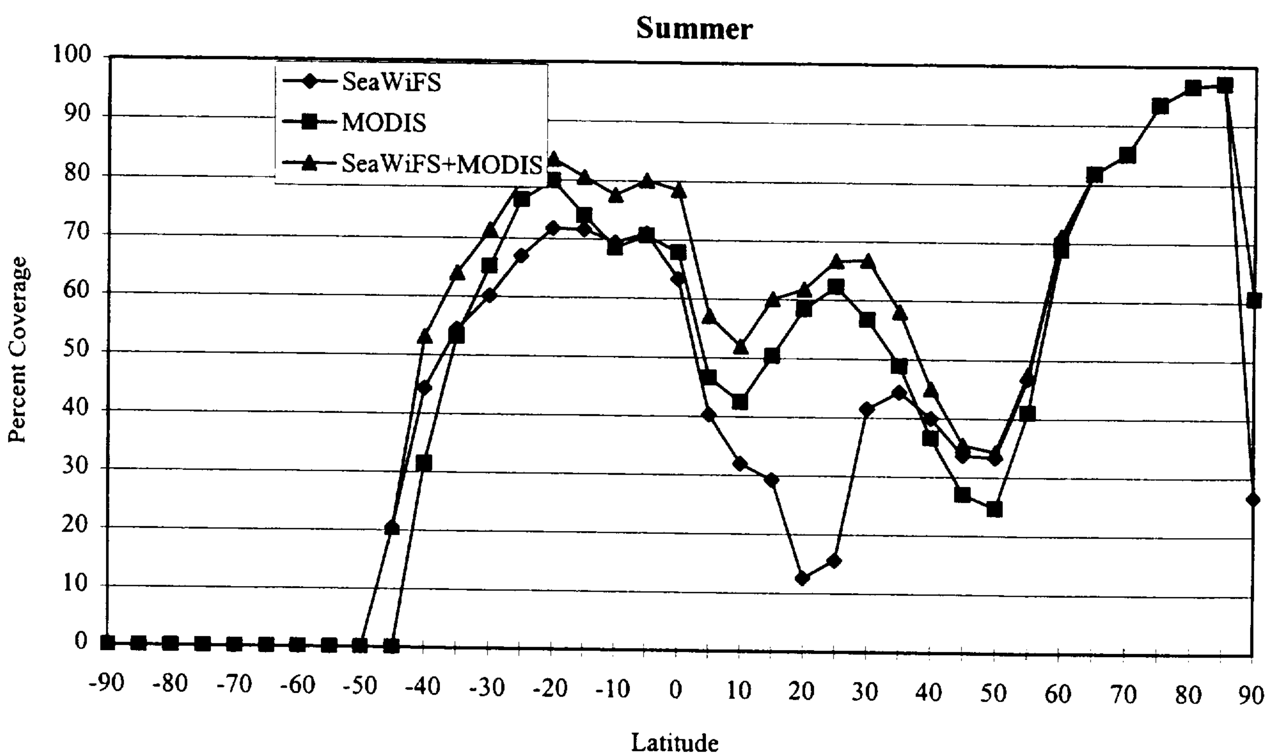
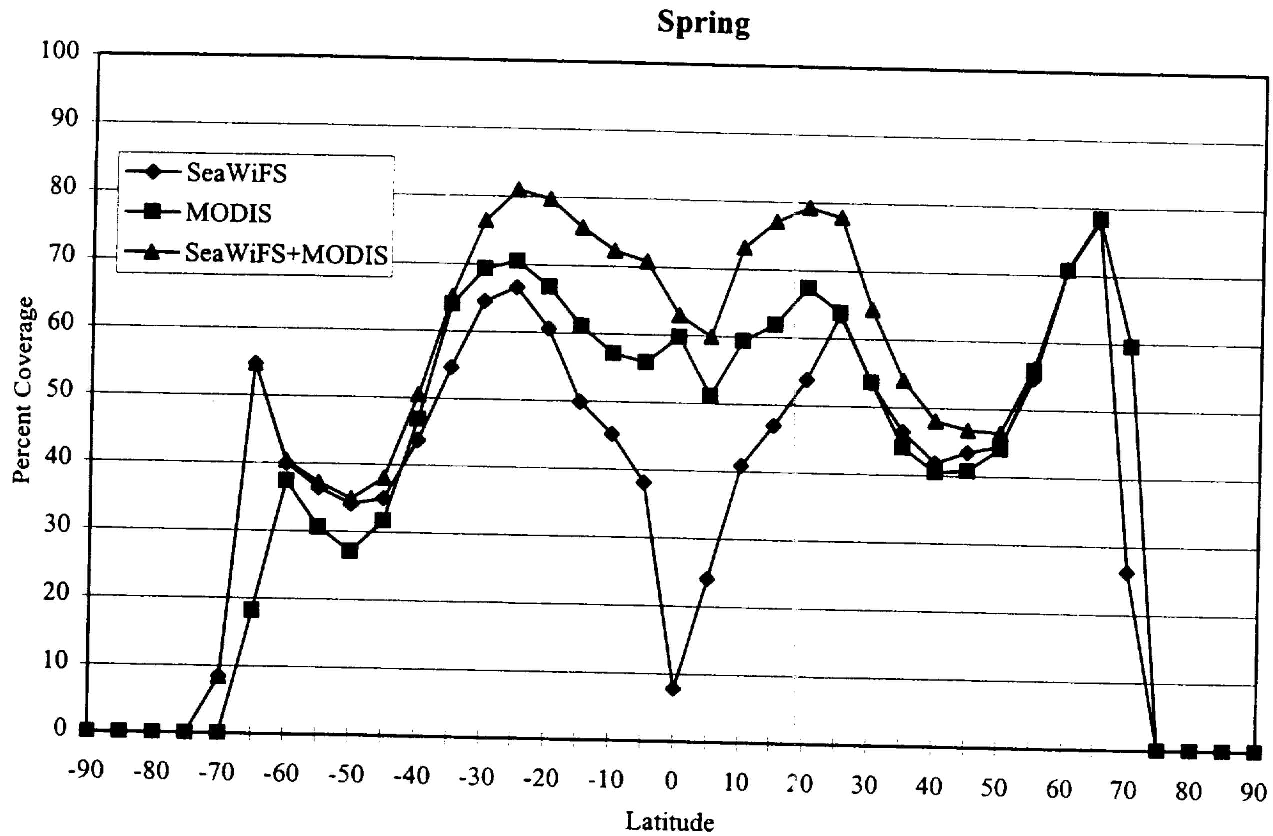


Figure 11a. Meridional analysis of mean four-day coverage for spring and summer.



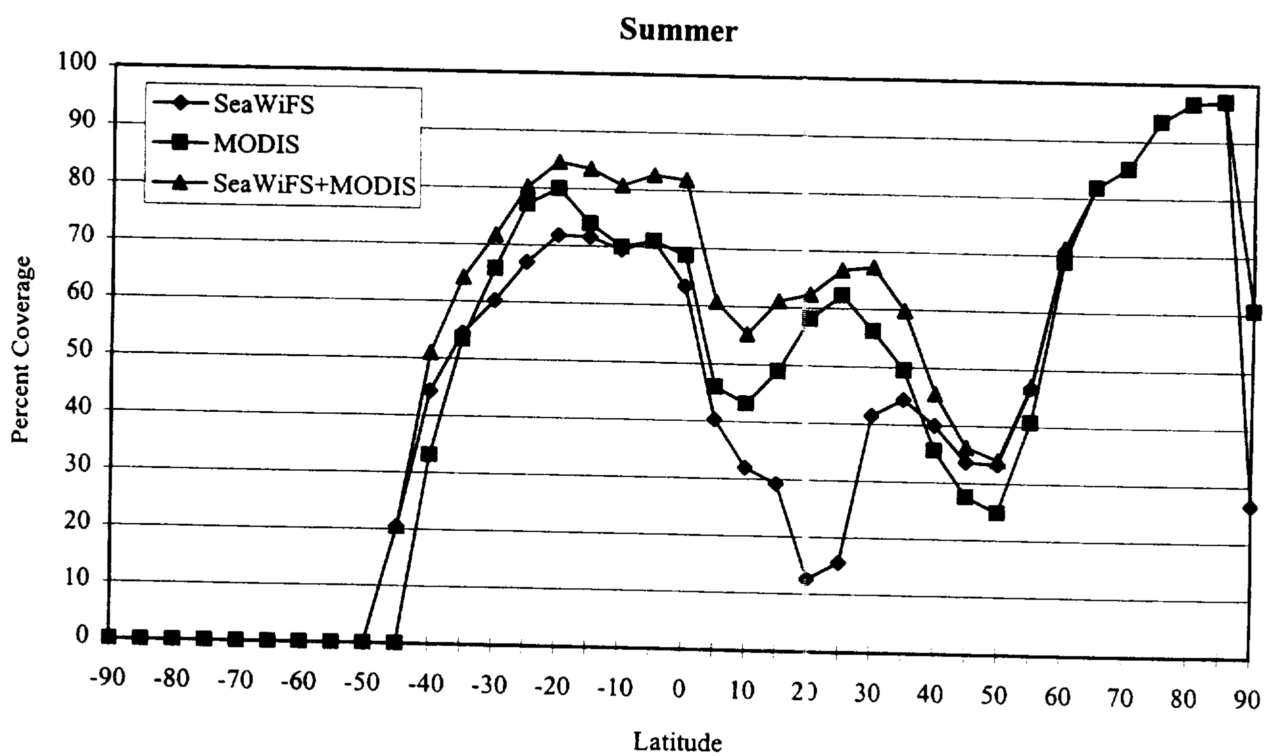
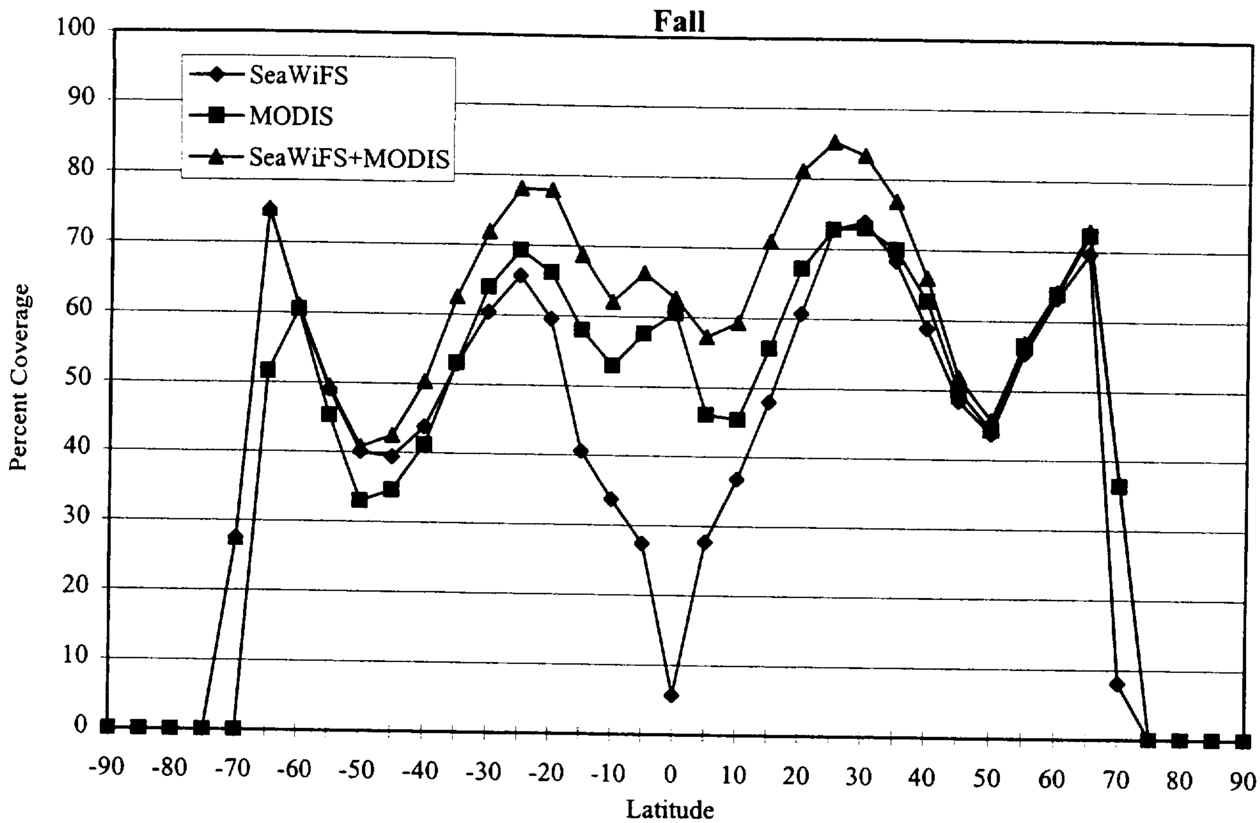


Figure 12a. Meridional analyis of maximum four-day coverage for spring and summer.



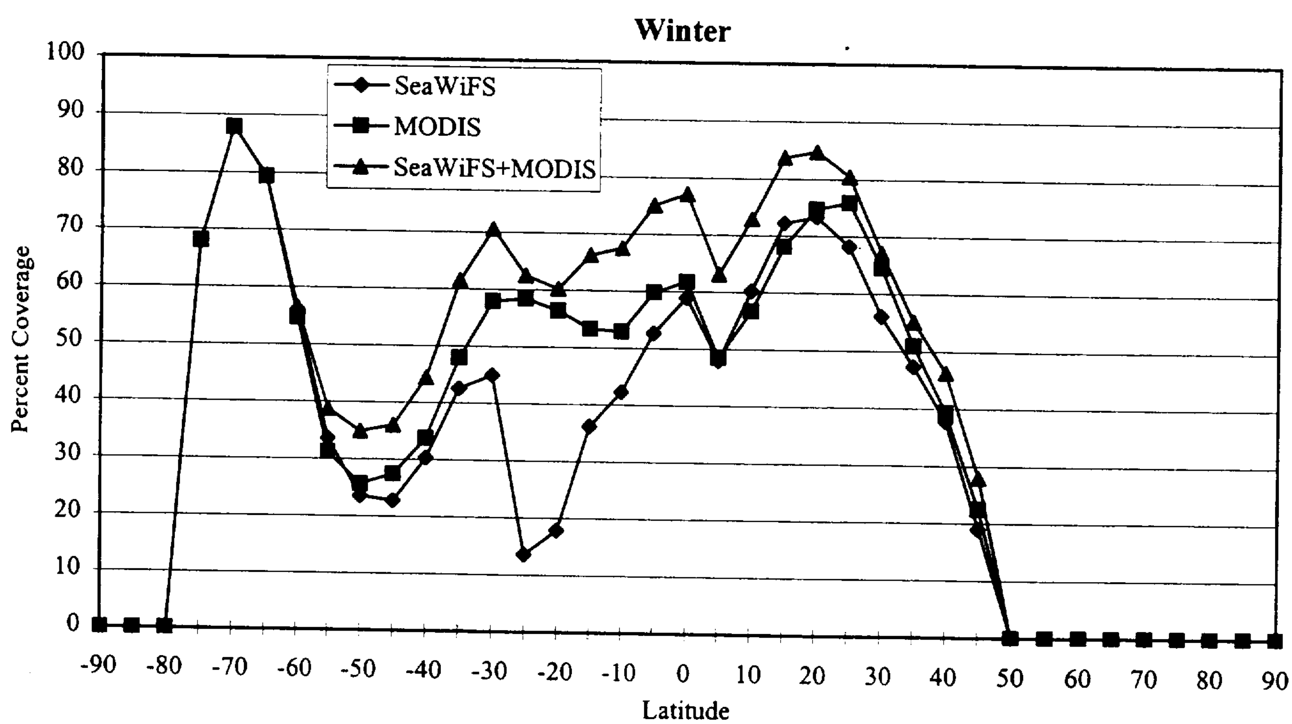


Figure 12b. Meridional analyis of maximum four-day coverage for fall and winter.

Table 5. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the spring, one-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0
70	6.7	21.6	21.7	223.9
65	37.8	38.4	38.4	1.6
60	31.9	31.9	31.9	0.0
55	22.5	22.5	22.5	0.0
50	16.6	16.5	17.0	2.4
45	15.8	15.6	17.0	7.6
40	14.6	13.7	16.0	9.6
35	16.3	15.9	18.4	12.9
30	19.4	17.6	21.8	12.4
25	24.1	22.0	29.5	22.4
20	20.5	25.0	35.0	70.7
15	18.9	24.5	36.1	91.0
10	15.7	20.9	30.9	101.4
5	9.2	16.0	21.5	133.7
0	1.6	20.9	21.7	1256.3
-5	12.3	19.8	26.2	113.0
-10	15.4	20.0	26.4	71.4
-15	19.9	22.5	30.4	52.8
-20	24.1	25.4	32.4	34.4
-25	24.4	27.1	31.7	29.9
-30	23.1	27.4	27.4	29.6
-35	18.1	24.2	24.5	35.4
-40	13.0	15.5	16.6	27.7
-45	11.2	10.5	12.3	9.8
-50	10.6	8.1	10.8	1.9
-55	10.7	8.4	10.9	1.9
-60	12.6	11.9	12.7	0.8
-65	20.8	6.9	21.0	1.0
-70	5.2	0.0	5.2	0.0
-75	0.0	0.0	0.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 6. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the summer, one-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	11.4	35.4	35.4	210.5
85	59.3	59.4	59.4	0.0
80	57.7	57.7	57.7	0.0
75	56.0	56.0	56.0	0.0
70	47.5	47.5	47.5	0.0
65	39.8	39.8	39.8	0.0
60	29.3	27.7	29.3	0.0
55	18.6	13.7	18.6	0.0
50	11.7	6.5	11.9	1.7
45	12.4	8.4	13.0	4.8
40	15.5	13.0	17.7	14.2
35	16.5	18.2	23.8	44.2
30	14.8	20.0	26.5	79.1
25	6.1	20.5	24.1	395.1
20	3.5	18.1	19.5	457.1
15	9.6	17.0	21.7	126.0
10	10.0	13.7	17.8	78.0
5	12.8	14.7	19.3	50.8
0	24.5	27.3	35.1	43.3
-5	29.0	30.7	38.0	31.0
-10	27.6	29.4	35.3	27.9
-15	29.7	34.0	38.7	30.3
-20	28.5	36.4	40.1	40.7
-25	25.1	32.3	35.6	41.8
-30	21.5	25.3	29.0	34.9
-35	18.1	18.7	24.1	33.1
-40	13.1	9.7	17.7	35.1
-45	6.3	0.0	6.3	0.0
-50	0.0	0.0	0.0	0.0
-55	0.0	0.0	0.0	0.0
-60	0.0	0.0	0.0	0.0
-65	0.0	0.0	0.0	0.0
-70	0.0	0.0	0.0	0.0
-75	0.0	0.0	0.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 7. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the fall, one-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0
70	4.8	18.8	18.8	291.7
65	30.6	31.1	31.1	1.6
60	24.2	24.2	24.2	0.0
55	21.1	21.1	21.1	0.0
50	16.5	16.7	21.1	27.9
45	18.4	18.9	19.9	8.2
40	24.1	25.6	27.1	12.4
35	28.7	30.5	34.2	19.2
30	31.4	28.2	35.1	11.8
25	30.3	27.1	36.3	19.8
20	20.8	22.8	30.6	47.1
15	17.3	18.8	26.1	50.9
10	12.3	13.8	19.1	55.3
5	8.5	13.5	18.2	114.1
0	1.6	20.8	21.5	1243.8
-5	10.7	21.8	28.7	168.2
-10	12.5	20.6	28.5	128.0
-15	16.8	23.1	31.2	85.7
-20	24.4	27.0	34.1	39.8
-25	23.7	27.6	31.2	31.6
-30	20.9	24.4	27.1	29.7
-35	17.3	18.8	21.5	24.3
-40	12.6	13.0	15.3	21.4
-45	12.8	11.6	14.1	10.2
-50	12.7	10.4	13.0	2.4
-55	15.1	14.0	15.2	0.7
-60	21.7	21.5	21.9	0.9
-65	29.3	13.9	29.7	1.4
-70	5.3	0.0	5.3	0.0
-75	0.0	0.0	0.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 8. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the winter, one-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0
60	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0
45	5.9	7.7	11.0	86.4
40	13.7	12.4	17.3	26.3
35	16.7	18.5	21.1	27.5
30	20.3	24.4	25.7	26.6
25	26.4	34.0	36.3	37.5
20	27.7	32.6	39.3	41.9
15	30.2	27.5	36.9	22.2
10	22.5	21.0	27.8	23.6
5	16.0	16.0	20.9	30.6
0	22.2	22.0	29.6	33.3
-5	20.3	22.3	30.9	52.2
-10	15.0	18.8	25.3	68.7
-15	12.3	18.2	25.6	108.1
-20	6.0	20.0	24.0	300.0
-25	3.4	19.8	20.4	500.0
-30	15.2	20.1	24.8	63.2
-35	14.2	14.9	20.2	42.3
-40	8.3	9.5	13.4	61.4
-45	6.4	8.5	11.4	78.1
-50	7.0	7.4	10.3	47.1
-55	9.9	8.9	11.1	12.1
-60	19.6	19.0	19.6	0.0
-65	34.2	34.2	34.2	0.0
-70	42.9	42.9	42.9	0.0
-75	36.5	36.5	36.5	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 9. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the spring, four-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0
70	26.3	60.8	60.9	131.6
65	78.0	78.4	78.5	0.6
60	70.7	70.8	70.9	0.3
55	54.6	55.6	56.1	2.7
50	44.5	43.7	46.1	3.6
45	43.5	41.3	45.9	5.5
40	41.9	39.9	45.8	9.3
35	46.4	44.4	50.8	9.5
30	53.5	51.6	59.7	11.6
25	63.5	62.4	72.3	13.9
20	53.8	67.0	78.0	45.0
15	46.9	61.9	78.0	66.3
10	40.9	59.0	74.2	81.4
5	24.1	49.9	59.3	146.1
0	7.8	58.2	60.6	676.9
-5	38.1	56.1	68.0	78.5
-10	45.2	58.1	69.9	54.6
-15	49.9	61.9	73.1	46.5
-20	60.6	66.7	76.3	14.6
-25	66.6	70.3	76.8	15.3
-30	64.5	70.0	74.2	15.0
-35	54.6	63.8	65.1	19.2
-40	43.7	46.3	50.1	14.6
-45	35.0	31.3	36.9	5.4
-50	34.1	27.5	34.8	2.1
-55	36.4	30.4	36.8	1.1
-60	40.0	37.3	40.4	0.4
-65	54.7	17.4	54.9	0.4
-70	8.4	0.0	8.4	0.0
-75	0.0	0.0	0.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 10. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the summer, four-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	26.7	60.7	60.7	127.3
85	97.0	97.1	97.1	0.1
80	96.6	96.6	96.6	0.0
75	93.5	93.5	93.5	0.0
70	85.2	85.2	85.2	0.0
65	81.9	81.9	81.9	0.0
60	70.7	68.9	71.2	0.7
55	46.8	41.0	47.6	1.7
50	33.3	24.7	34.3	3.0
45	33.7	27.1	35.5	5.3
40	40.0	36.6	45.0	12.5
35	44.4	48.9	58.1	30.9
30	41.5	56.7	66.8	61.0
25	15.6	62.3	66.7	327.6
20	12.6	58.4	61.8	390.5
15	29.3	50.4	60.1	105.1
10	32.0	42.5	52.0	62.5
5	40.3	46.6	57.1	41.7
0	63.3	67.9	78.5	24.0
-5	71.1	70.7	80.1	12.7
-10	69.5	68.6	77.6	11.7
-15	71.6	74.0	80.6	11.7
-20	71.8	79.9	83.6	16.4
-25	67.0	76.6	79.9	19.3
-30	60.2	65.2	71.4	18.6
-35	54.4	53.2	64.0	17.6
-40	44.3	31.5	53.1	19.9
-45	20.5	0.0	20.5	0.0
-50	0.0	0.0	0.0	0.0
-55	0.0	0.0	0.0	0.0
-60	0.0	0.0	0.0	0.0
-65	0.0	0.0	0.0	0.0
-70	0.0	0.0	0.0	0.0
-75	0.0	0.0	0.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 11. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the fall, four-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0
70	8.1	38.1	38.1	370.4
65	69.7	72.5	72.9	4.6
60	63.3	64.0	64.2	1.4
55	55.4	56.6	56.8	2.5
50	43.8	44.3	45.3	3.4
45	48.5	49.8	51.5	6.2
40	58.8	63.4	65.7	11.7
35	68.4	70.6	75.9	11.0
30	73.9	71.8	79.7	7.8
25	72.8	72.0	80.9	11.1
20	60.7	68.0	78.3	29.0
15	48.0	55.8	68.6	42.9
10	36.8	43.8	56.1	52.4
5	27.7	44.7	56.6	104.3
0	5.7	59.7	61.7	982.5
-5	27.4	57.9	67.1	144.9
-10	33.7	52.7	64.5	91.4
-15	40.6	57.9	69.2	70.4
-20	59.5	65.9	75.5	27.9
-25	65.7	68.9	74.7	13.7
-30	60.4	64.5	69.3	14.7
-35	52.9	53.1	59.8	13.0
-40	43.8	40.9	48.0	9.6
-45	39.4	34.0	41.4	5.1
-50	40.1	33.3	40.6	1.2
-55	49.1	44.9	49.3	0.4
-60	60.7	60.1	61.0	0.5
-65	74.6	51.2	74.9	0.4
-70	27.5	0.0	27.5	0.0
-75	0.0	0.0	0.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

Table 12. Meridional coverage for SeaWiFS (S), MODIS (M), and combined SeaWiFS/MODIS (S+M) for the winter, four-day, mean coverage case. The percent increase (%+) gained by adding MODIS is also listed.

Lat	S	M	S+M	%+
90	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0
60	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0
45	19.0	22.5	27.5	44.7
40	37.8	39.4	45.7	20.8
35	47.4	51.0	55.4	16.9
30	56.1	64.3	67.4	20.1
25	68.2	76.5	80.1	17.4
20	73.4	74.3	84.0	14.4
15	72.3	68.9	82.3	13.8
10	60.2	57.3	70.5	17.1
5	48.0	48.1	60.7	26.4
0	58.9	61.8	74.0	25.6
-5	52.7	60.2	71.6	35.9
-10	42.3	54.1	64.2	51.8
-15	36.2	53.4	62.5	72.6
-20	17.9	56.6	61.2	241.9
-25	13.6	57.9	59.3	336.0
-30	45.0	58.0	69.1	53.6
-35	42.6	47.9	59.5	39.7
-40	30.3	33.2	42.4	40.0
-45	22.8	26.2	32.2	41.2
-50	23.6	25.8	28.8	22.0
-55	33.6	30.8	35.5	5.7
-60	56.1	54.2	56.4	0.1
-65	79.5	79.2	79.5	0.0
-70	87.9	87.9	87.9	0.0
-75	68.0	68.0	68.0	0.0
-80	0.0	0.0	0.0	0.0
-85	0.0	0.0	0.0	0.0
-90	0.0	0.0	0.0	0.0

The addition of MODIS provides only slightly more total coverage at higher latitudes. The large increase in coverage with the addition of MODIS at 90° degrees is a coincidental result of binning. It is interesting to note the apparent asymmetry in the coverages at very high latitudes near instrument turn on and turn off. MODIS provides more coverage at turn on (Northern Hemisphere), SeaWiFS provides more at turn off (Southern Hemisphere). This is a result of sun glint produced by high winds in the southern oceans. The tilting SeaWiFS instrument avoids this sun glint. Note in Table 5 that MODIS increase coverage by 223.9% at 70° while contributing nothing to the total coverage at -70°.

Several effects contribute to the meridional patterns found in Figures 9 through 12. The spring and fall cases display a pattern of four relative maxima for SeaWiFS, MODIS, and combined coverages. The pattern can be explained in terms of sun glint contamination and cloud cover. Looking only at the SeaWiFS coverage for the spring case in Figures 9 (Table 5), we see the coverage increasing from 0% at -75° latitude to 20.8% at -65°. The coverage then falls to 10.6% at -50°. This minimum is a result of the increase in cloudiness found at mid to high latitudes. The coverage then increases to 24.4% at -25° as cloudiness decreases. The coverage then falls to 1.6% at 0° due to sun glint contamination. This pattern mirrors itself in the Northern Hemisphere as the cloud cover produces a coverage minimum at 45° to 50°. The fall case produces a comparable meridional pattern. A similar meridional pattern is observed for both the spring and fall maximum coverage case for both MODIS and the combined SeaWiFS/MODIS coverages. The above meridional pattern is also observed for the spring and fall four-day mean and the spring four-day maximum cases.

The summer analysis also reveals a meridional dependence on sun glint and cloud cover. Examining only the SeaWiFS coverage in we find a sun glint induced minimum of 3.5% at 20° and a much less pronounced cloud-induced minimum of 11.7% at 50°. Similar patterns are observed for both MODIS and the combined SeaWiFS/MODIS coverages. The summer analyses produce maxima for 75° to 85° as sun glint and coverage gaps disappear. The winter cases display somewhat of a mirror image to the summer cases. However the high latitude peaks (-65° to -75°) are not as pronounced as in the summer cases. This is a result of several factors. The southern region is cloudier than its northern counterpart. In addition, increased surface wind speeds and less land surface increases the sun glint interference in the Southern Hemisphere.

4.0. Conclusions

We investigated the merits of supplementing SeaWiFS ocean measurements with MODIS ocean measurements in terms of enhanced coverage. The mean and maximum combined coverages were determined by examining orbital alignments for four seasons: spring and fall equinoxes, and summer and winter solstices. Analysis was also performed to discern the meridional distribution of ocean coverage for both sensors separately and combined.

The combined SeaWiFS/MODIS coverages are found to provide substantial increases in coverages over the SeaWiFS only coverages for all four seasons for both mean and maximum coverage cases. The combined SeaWiFS/MODIS mean coverage provides an increase of 40.0% to 46.5% over SeaWiFS alone and the maximum one-day coverage provides and increase of 44.0% to 51.6%. The increase in the four-day coverages for the combined case ranges from 29.3% to 35.1% for mean coverage and 31.6% to 38.5% for maximum coverage. The coverage analyses reveal seasonally dependent effects of cloud cover and sun glint. Enhancements in coverages for the combined cases are especially significant near the solar declination for the one-day coverage cases. More modest coverage enhancements are observed near the declination for the four-day coverage cases. Our meridional analyses confirm the enhancement in combined coverages near the solar declination.

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6. AUTHOR(S)
Robert H. Woodward and Watson W. Gregg

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

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13. ABSTRACT *(Maximum 200 words)*

Ocean coverages of SeaWiFS and MODIS were assessed for three seasons by considreing monthly mean values of surface winds speeds and cloud cover. Mean and maximum coverages combined SeaWiFS and MODIS by considering combined coverages for ten-degree increments of the MODIS orbital mean anomaly. From this analysis the mean and maximum combined coverages for SeaWiFS and MODIS were determined for one and four-day periods for spring, summer, and winter seasons. Loss of coverage due to Sun glint and cloud cover were identified for both the individual and combined cases.

Our analyses indicate that MODIS will enhance ocean coverage for all three seasons examined. The combined SeaWiFS/MODIS show an increase of coverage of 42.2% to 48.7% over SeaWiFS alone for the three seasons studied; the increase in maximum one day coverage ranges from 47.5% to 52.0%. The increase in four-day coverage for the combined case ranged from 31.0% to 35.8% for mean coverage and 33.1% to 39.2% for maximum coverage.

We computed meridional distributions of coverages by binning the data into five-degree latitude bands. Our analysis shows a strong seasonal dependence of coverage. In general the meridional analysis indicates that increase in coverages for SeaWiFS/MODIS over SeaWiFS alone are greatest near the solar declination.

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